octoScope

Lecture 4: Exponential Complexity of Wireless Test

A lecture series by octoScope

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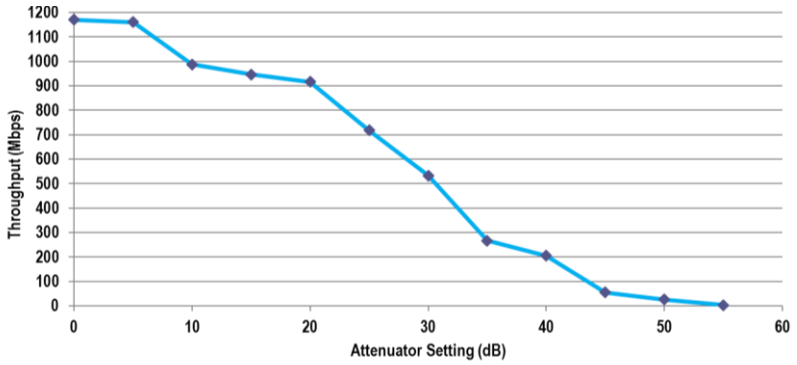
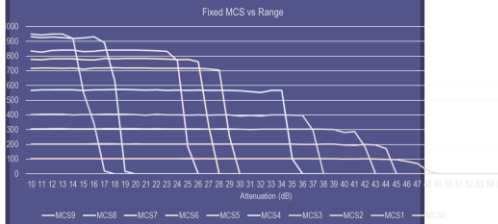
Maximum performance

1.3 Gbps



DVT



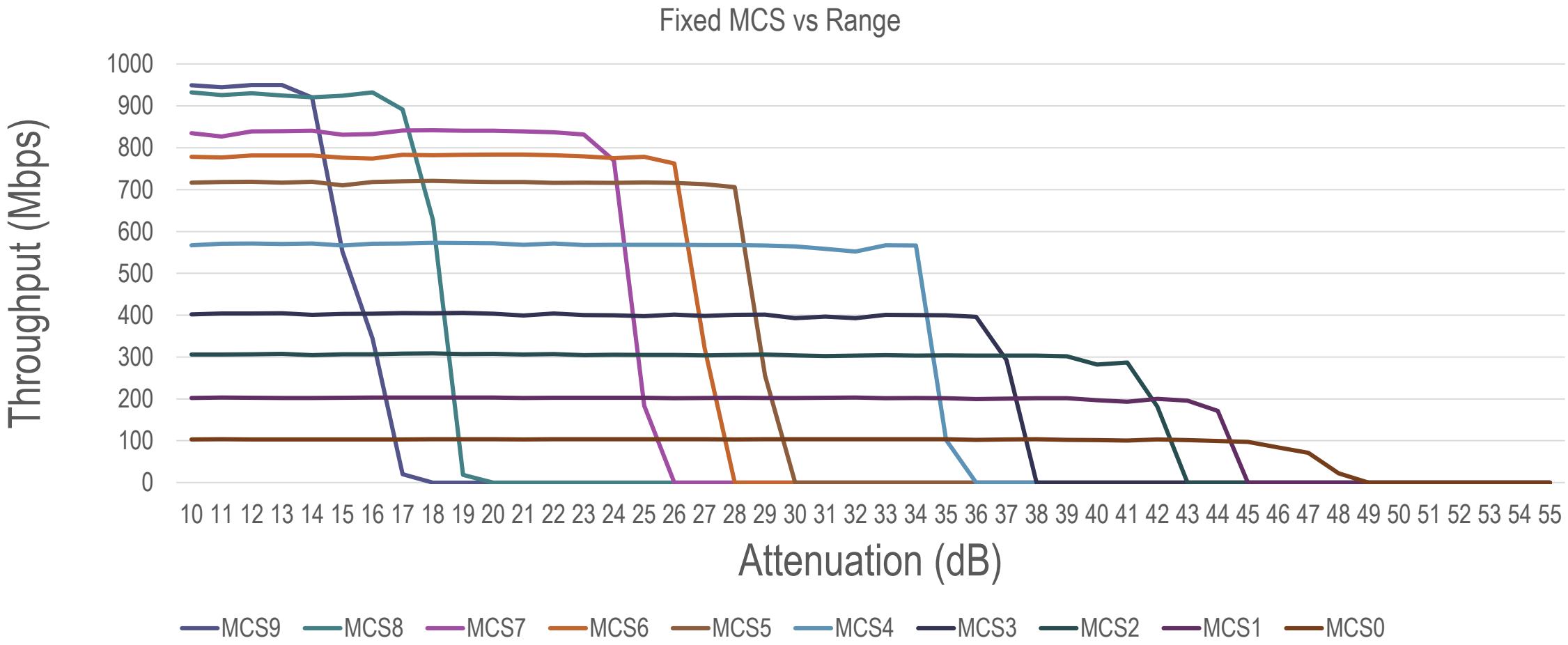
Video quality index	CCI Load, %	ACI, dBm	ACI Load, %
90	10	- 50	80
70	20	- 60	70
60	30	- 70	40
50	40	-80	30
40	50		
30	60		
	70		
	80		
	90		

Real world

Uncontrolled

DVT = design verification test

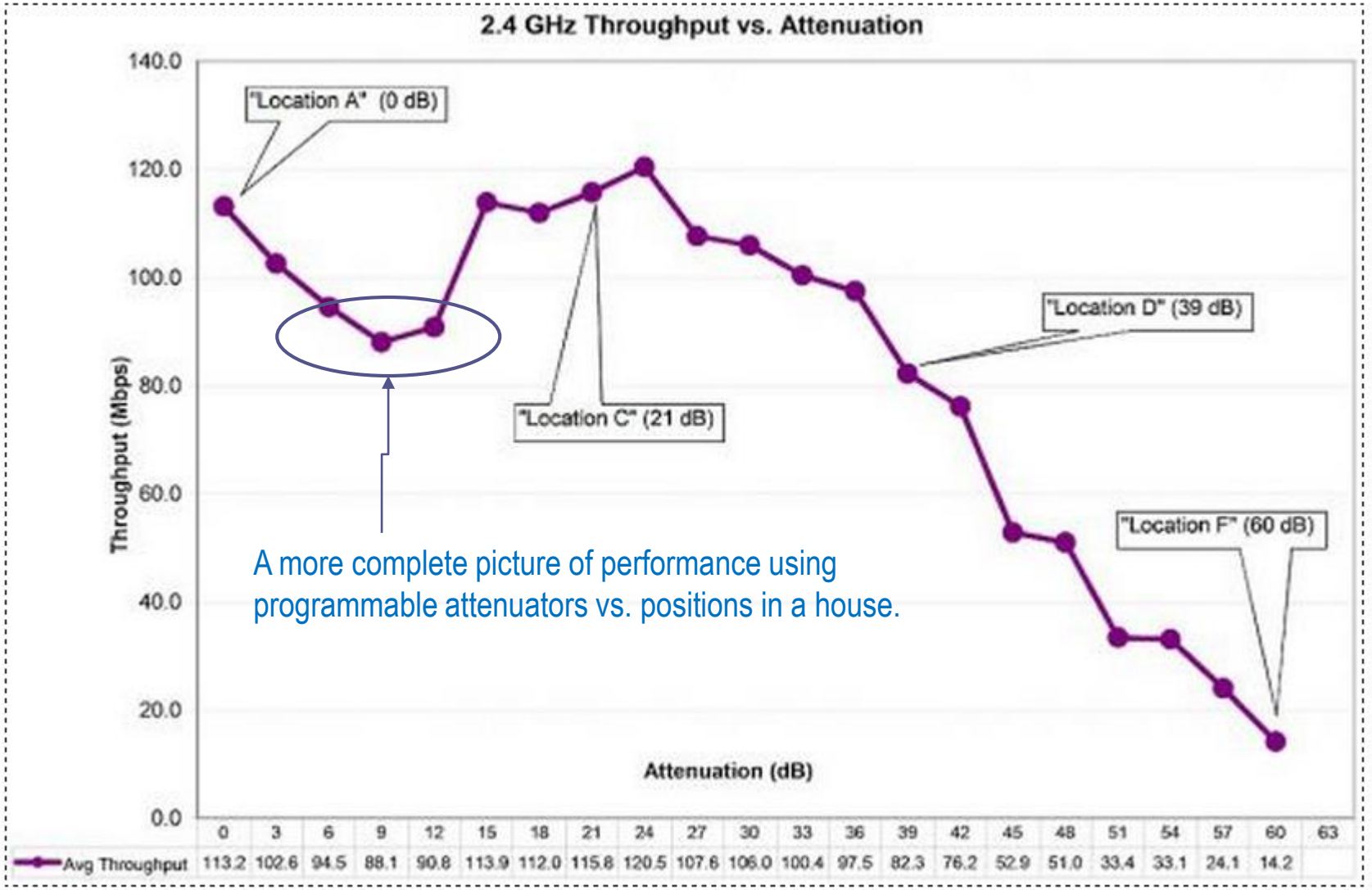
MCS Sweep



MCS = modulation coding scheme

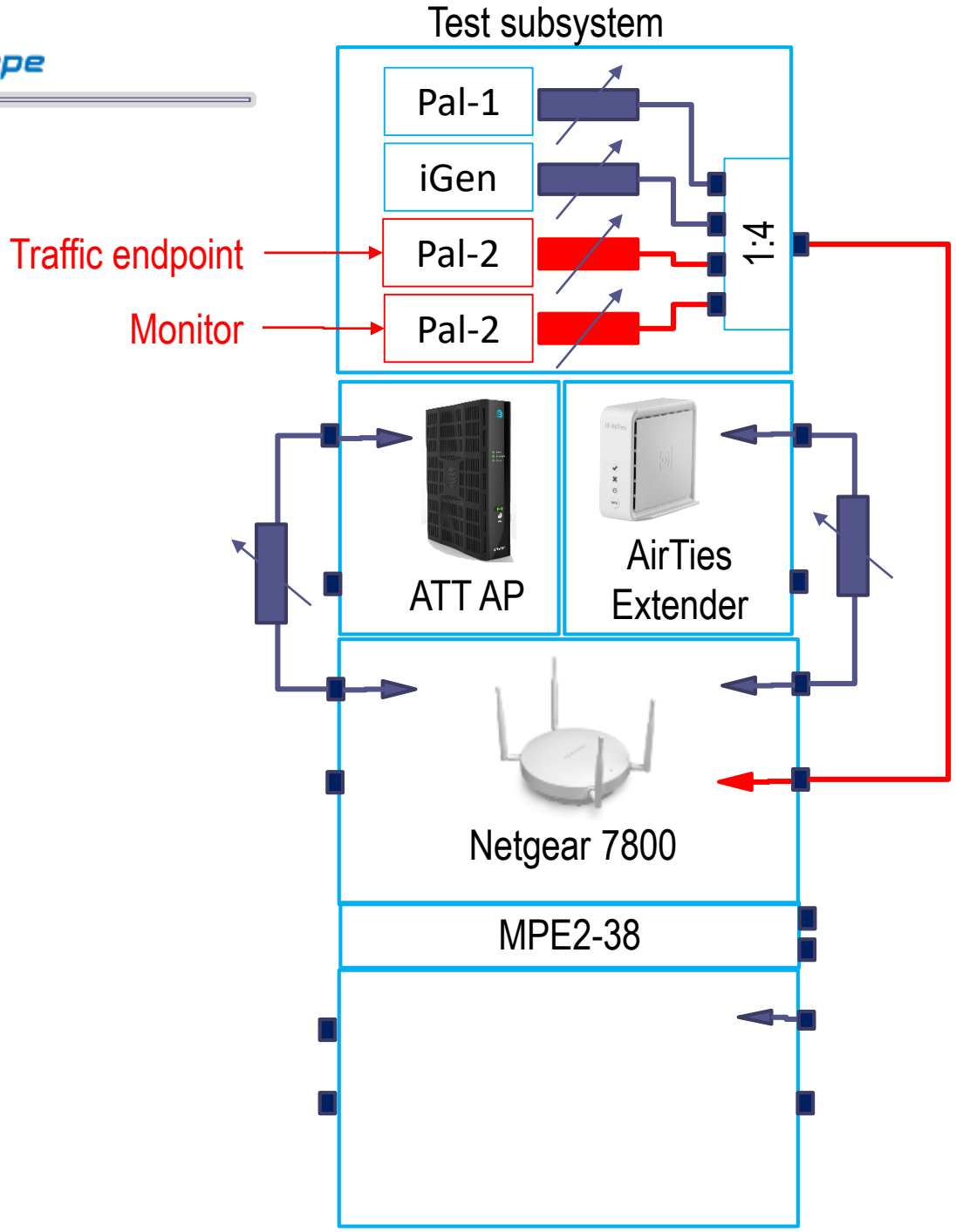
Real Life Rate Adaptation

Source: http://www.smallnetbuilder.com/images/stories/wireless/how_to_test_wireless/2-4ghz_mpe_test_points.jpg



octoBox MPE Test Location Attenuations - 2.4 GHz

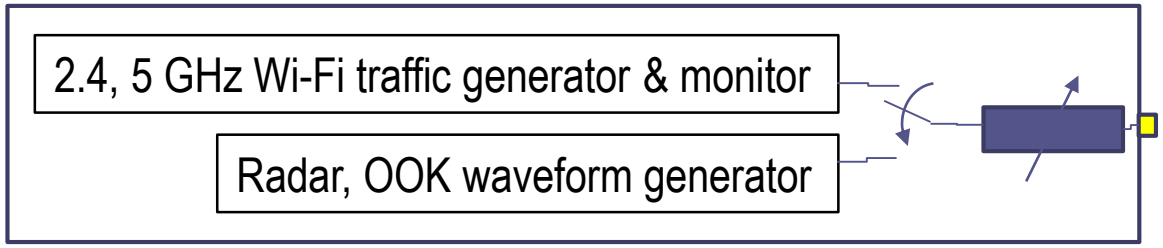
Credit: SmallNetBuilder.com



Demo of Pal and iGen ***Monitoring*** Capabilities

Live demo

iGen Interference Generator

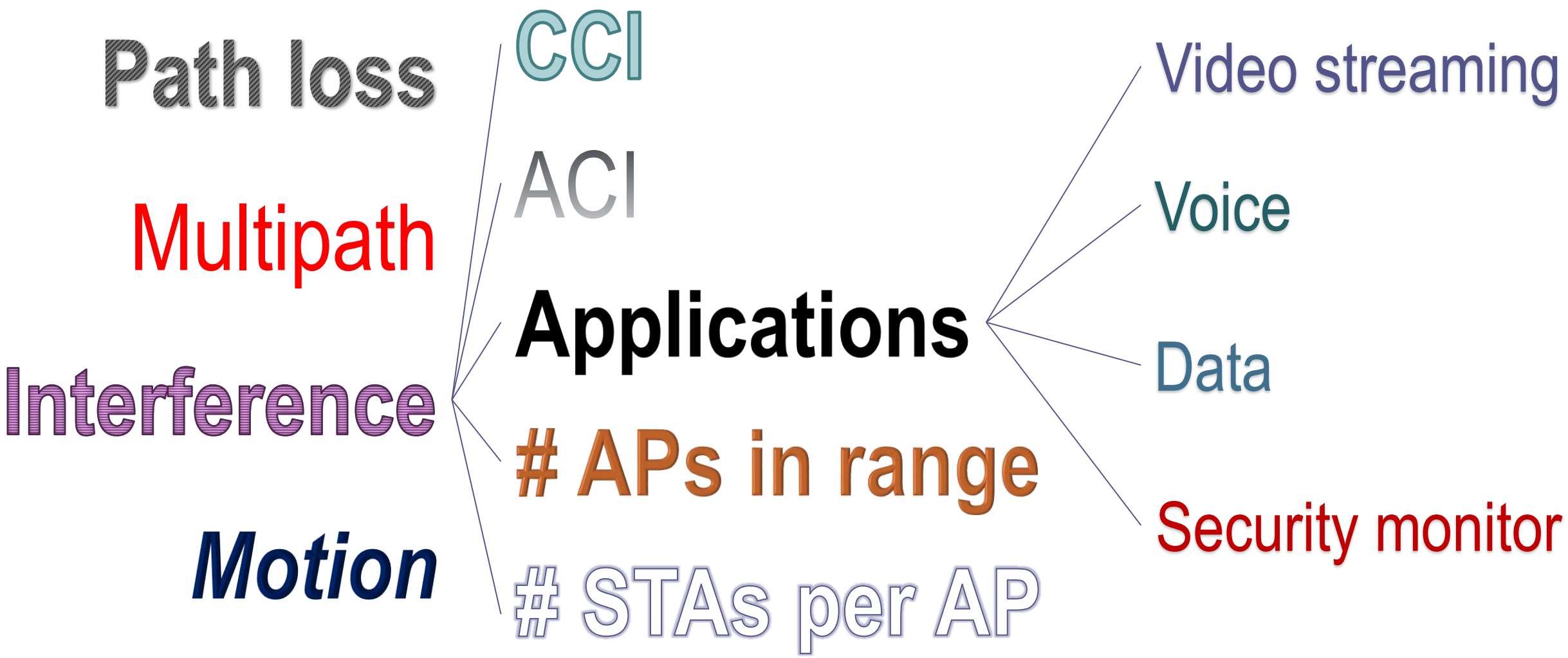


Live demo

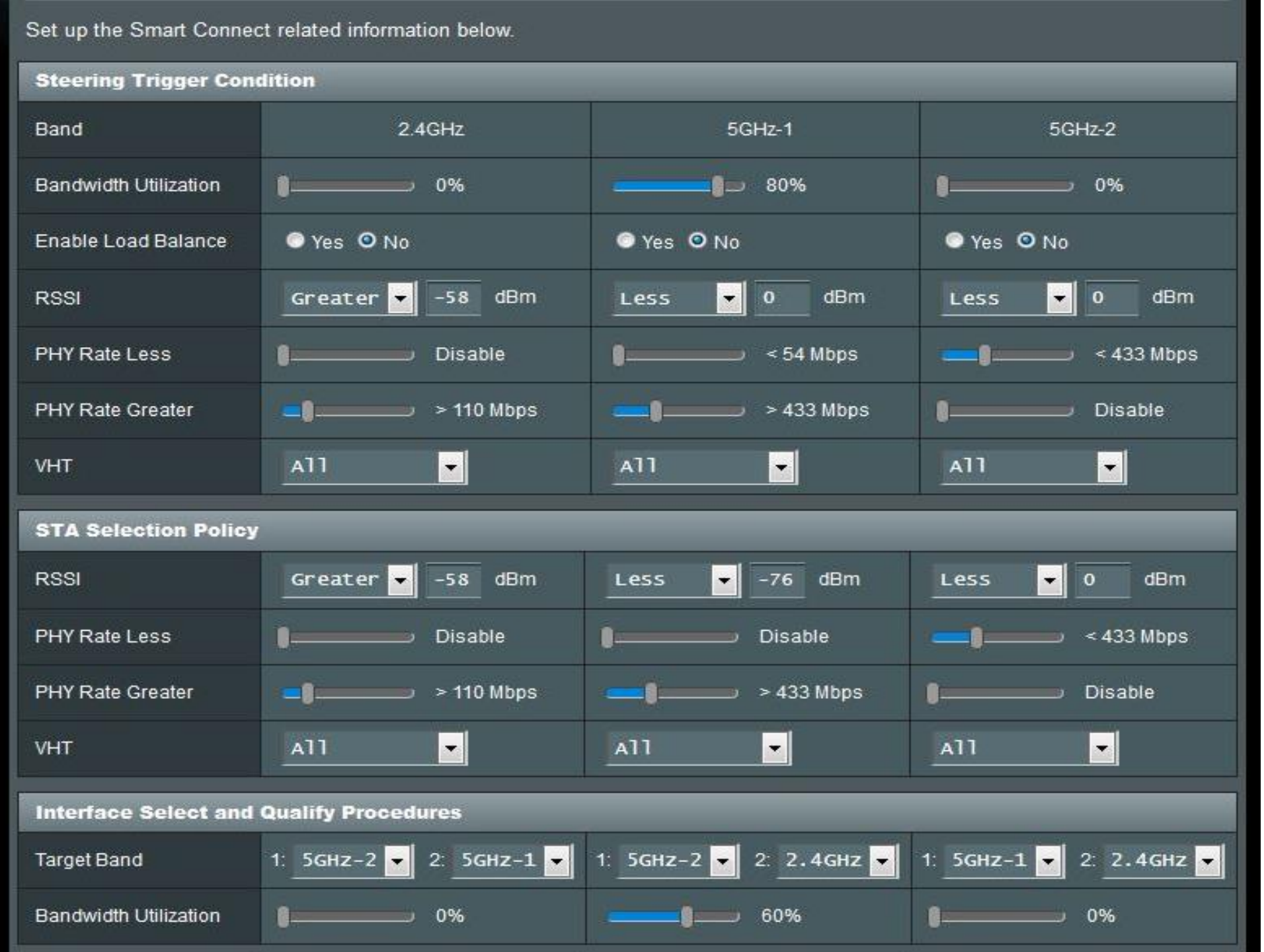
Wi-Fi traffic replay from PCAP captures
OOK waveforms between 500 MHz and 6 GHz
User definable waveforms downloadable as CSV files

CSV = comma separated variable
OOK = on off keying

Real World Variables



CCI = co-channel interference
ACI = adjacent channel interference



Example of ***Band Steering*** Test

Asus RT-AC3200 router

Live demo

802.11 r/k/v

Assist in band steering and load balancing

11r Fast Roaming	11k Radio Resource Measurements	11v Wireless Network Management
Address the requirements of voice traffic to ensure that call quality is maintained when a mobile station transitions from one AP to another	Standardizes layer 2 mechanisms for discovery and monitoring WLAN devices, their power levels, PHY configuration and network activity	Builds on the network measurement mechanisms defined by 11k and introduces network management functions

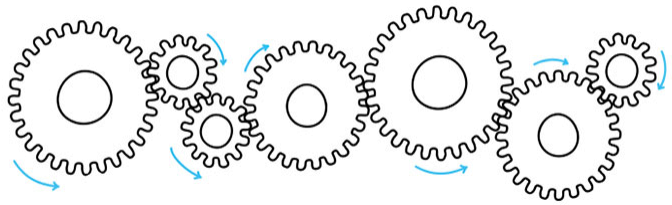
Exponentially Increasing Wireless Test Complexity

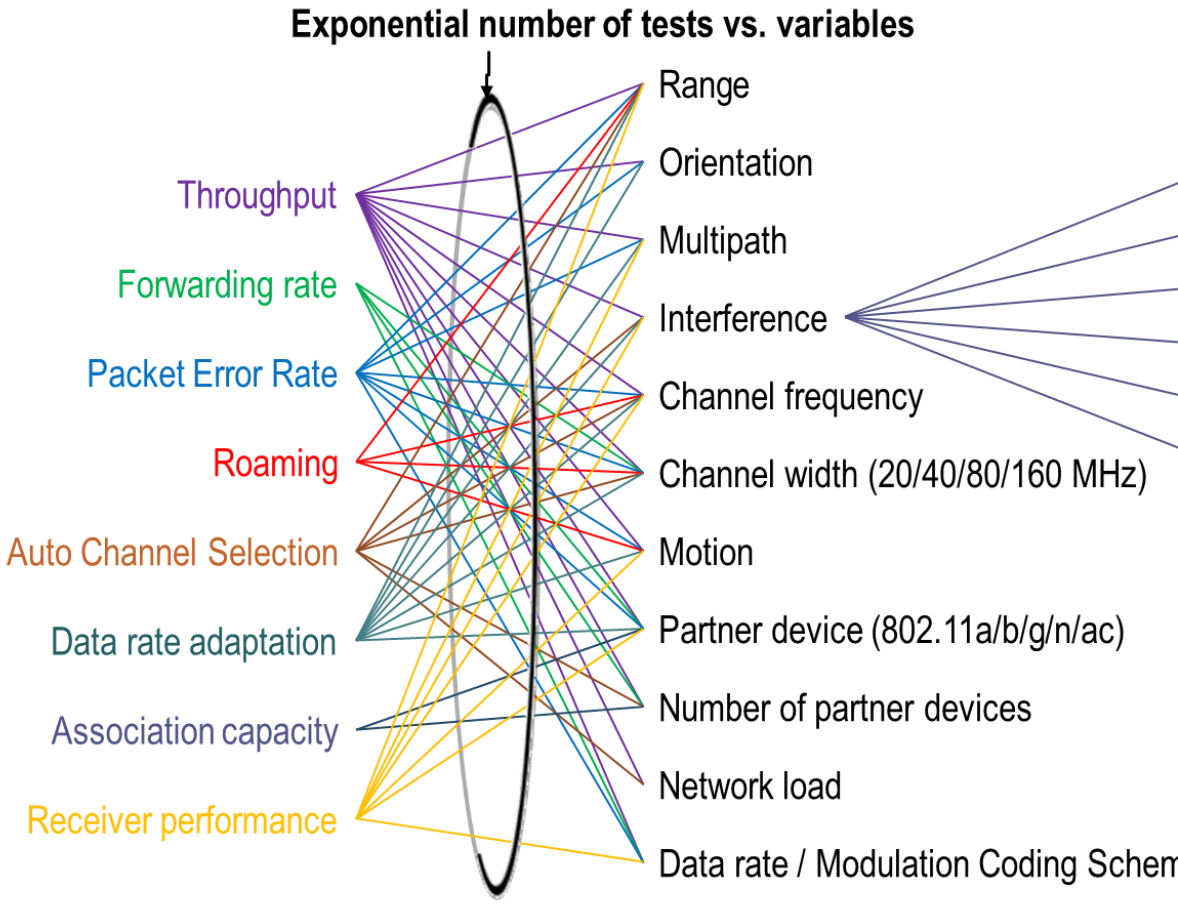
New Wi-Fi capabilities: 11ac/ax, load balancing, meshing

⇒ New tests that depend on many variables

⇒ Each new capability adds multiple test cases

⇒ New adaptation techniques





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- 802.11ac wave 2; 802.11ax
  - OFDM, OFDMA, beamforming, MU-MIMO
- Extender / mesh
- Roaming and mobility

Short break

- Coexistence
- IEEE recommended test practices

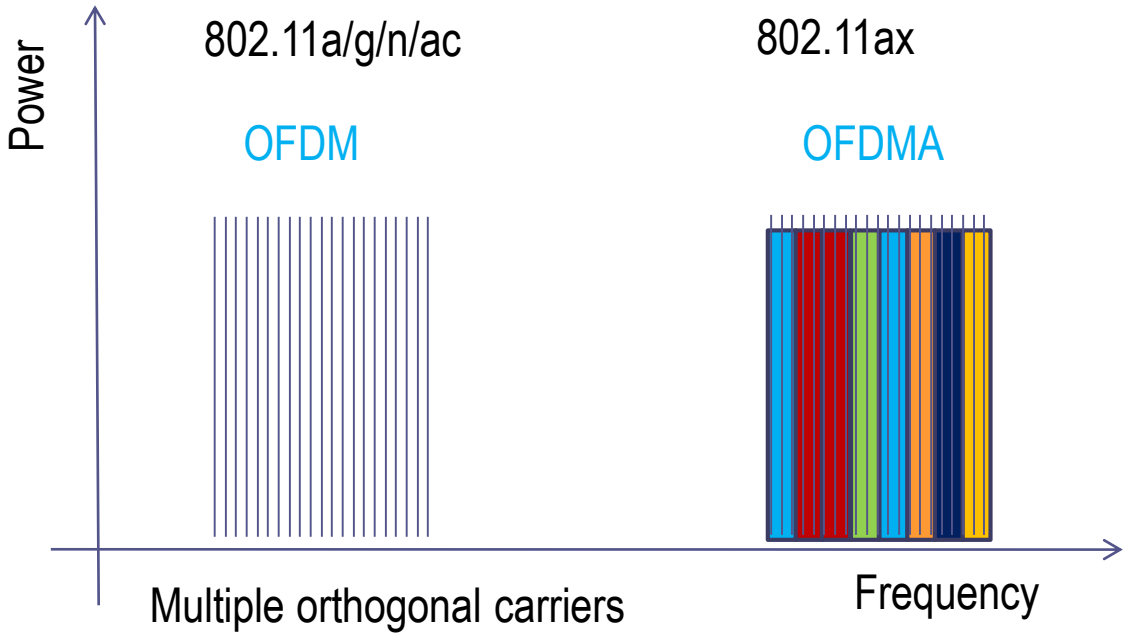
12:30 – 1:00 **Lunch**

1:00 **Live demonstrations, Q&A**

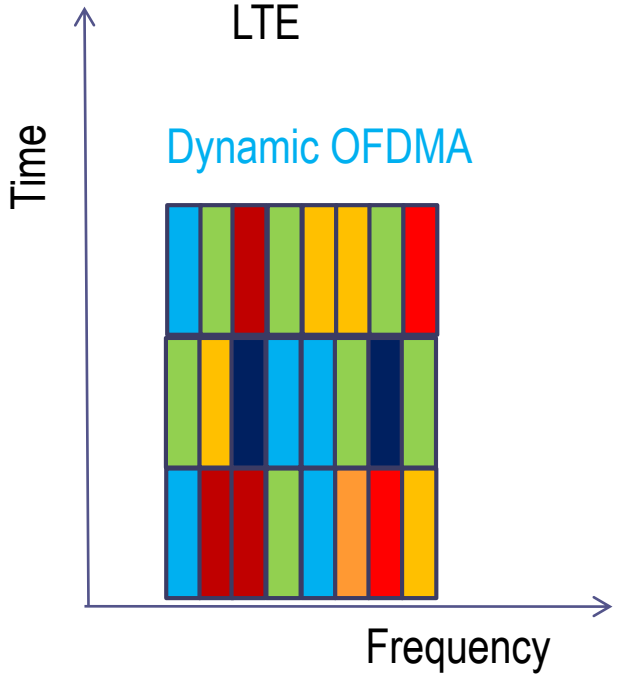
Adaptation Parameters for 802.11a/b/g/n/ac/ax

Adaptation	11a	11b	11g	11n	11ac wave-1	11ac wave 2	11ax
Modulation	DBPSK, DQPSK, 16-QAM, 64-QAM	DBPSK, DQPSK	DBPSK, DQPSK, 16-QAM, 64-QAM	DBPSK, DQPSK, 16-QAM, 64-QAM	DBPSK, DQPSK, 16-QAM, 64-QAM 256-QAM	DBPSK, DQPSK, 16-QAM, 64-QAM 256-QAM	16-QAM, 64-QAM 256-QAM 1024-QAM
Spread Spectrum Techniques	OFDM	DSSS	OFDM	OFDM	OFDM	OFDM	OFDMA
Coding rate	1/2, 2/3, 3/4		1/2, 2/3, 3/4	1/2, 2/3, 3/4, 5/6	1/2, 2/3, 3/4, 5/6	1/2, 2/3, 3/4, 5/6	1/2, 2/3, 3/4, 5/6
# spatial streams	1	1	1	1-4	1-3	1-4	1-8
Channel width	20MHz	20MHz	20MHz	20MHz, 40MHz	20MHz, 40MHz, 80MHz	20MHz, 40MHz, 80MHz, 80+80MHz, 160 MHz	20MHz, 40MHz, 80MHz, 80+80MHz, 160 MHz
Guard Interval (GI)	800ns	800ns	800ns	400ns/800ns	400ns/800ns	400/800 ns	800ns, 1.6us, 3.2us
Max data rate	54Mbps	11Mbps	54Mbps	600Mbps	1.3Gbps	3.5Gbps	65.3Gbps

OFDM and OFDMA



Frequency allocation per user is continuous vs. time



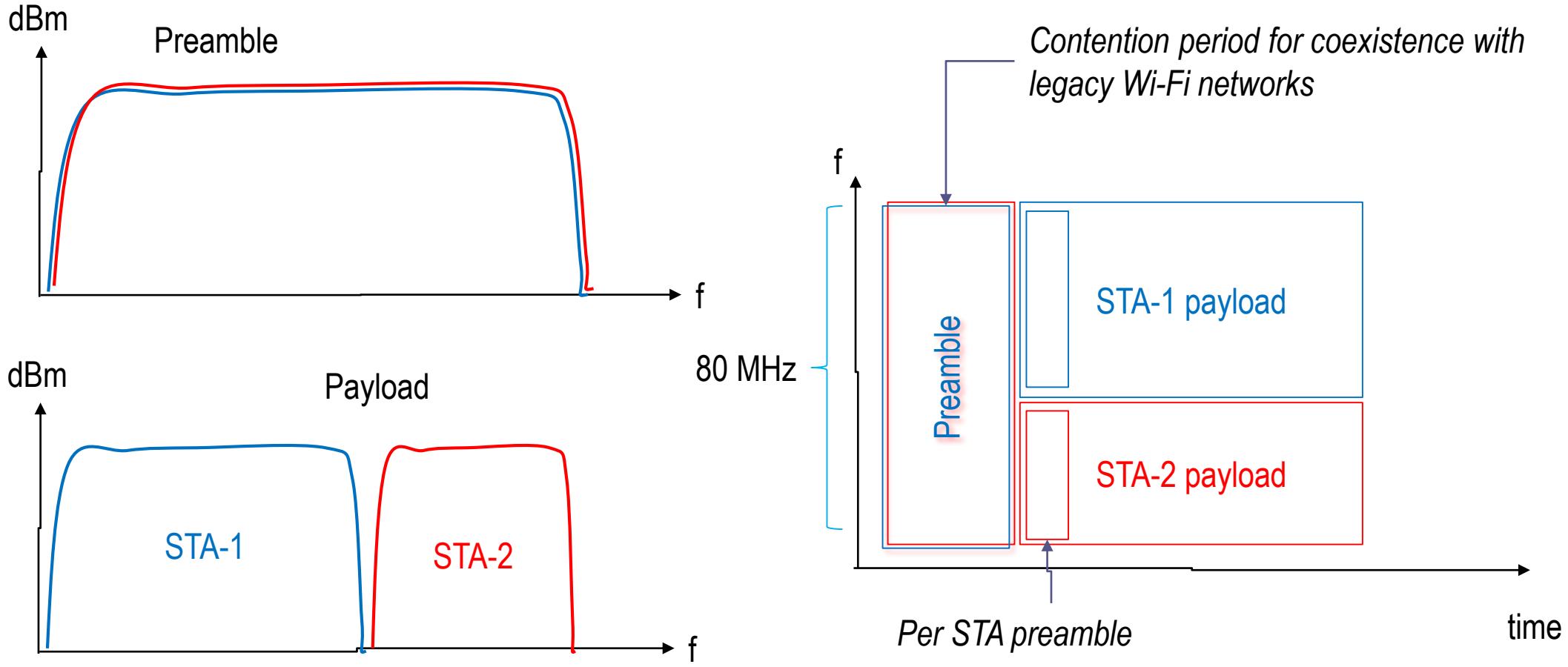
Frequency allocation per user is dynamic vs. time slots

User 1 | User 2 | User 3 | User 4 | User 5

OFDM = orthogonal frequency division multiplexing
OFDMA = orthogonal frequency division multiple access

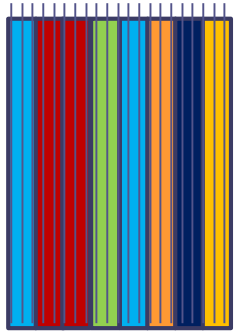
802.11ax Resource Unit (RU) Allocation

Credit: National Instrument



Scaling Network Capacity

Frequency multiplexing *802.11ax OFDMA*



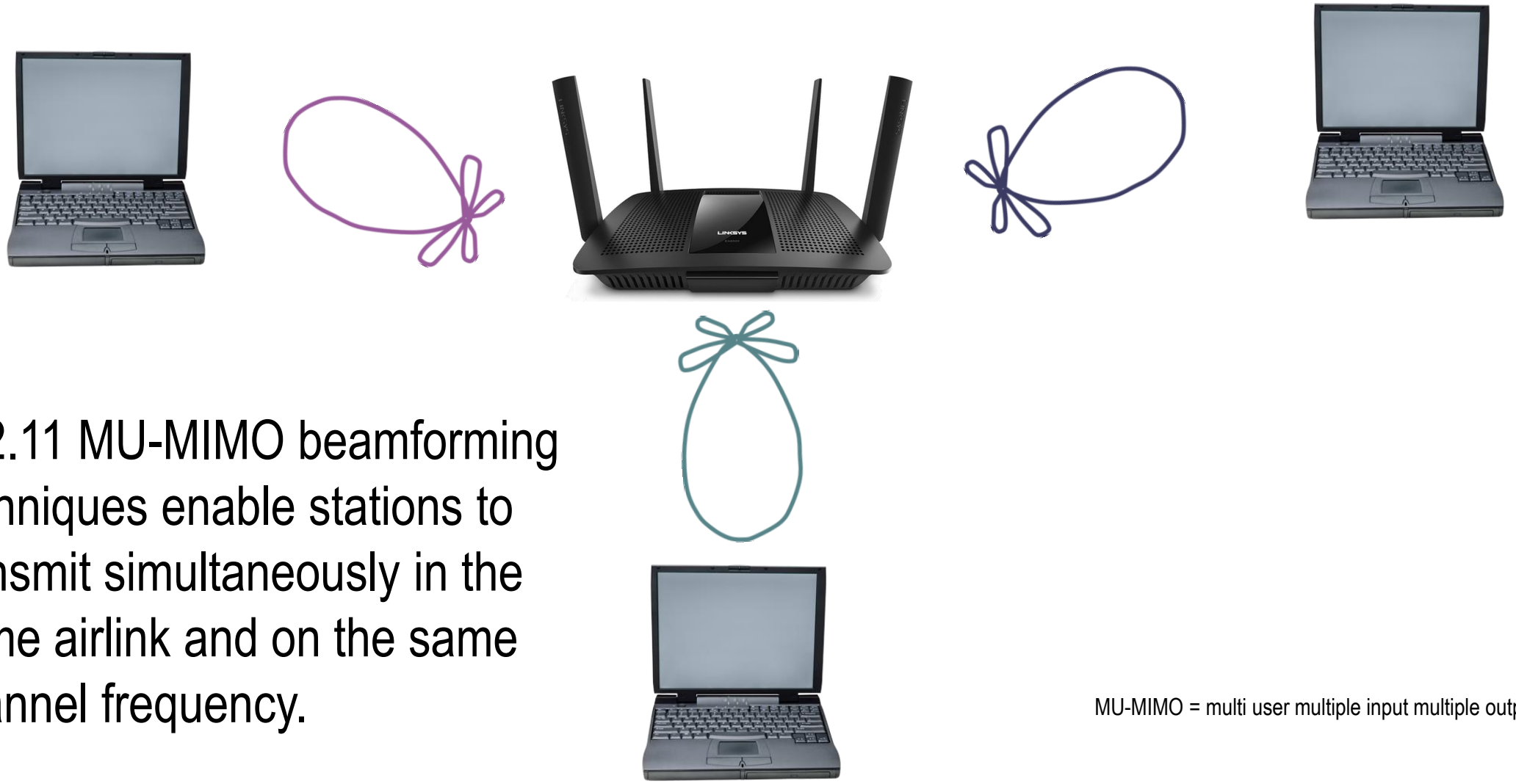
Spatial multiplexing *802.11ac MU-MIMO*

MU-MIMO = multi-user MIMO

Conventional RF Propagation – One Device at a Time

CSMA /CA contention

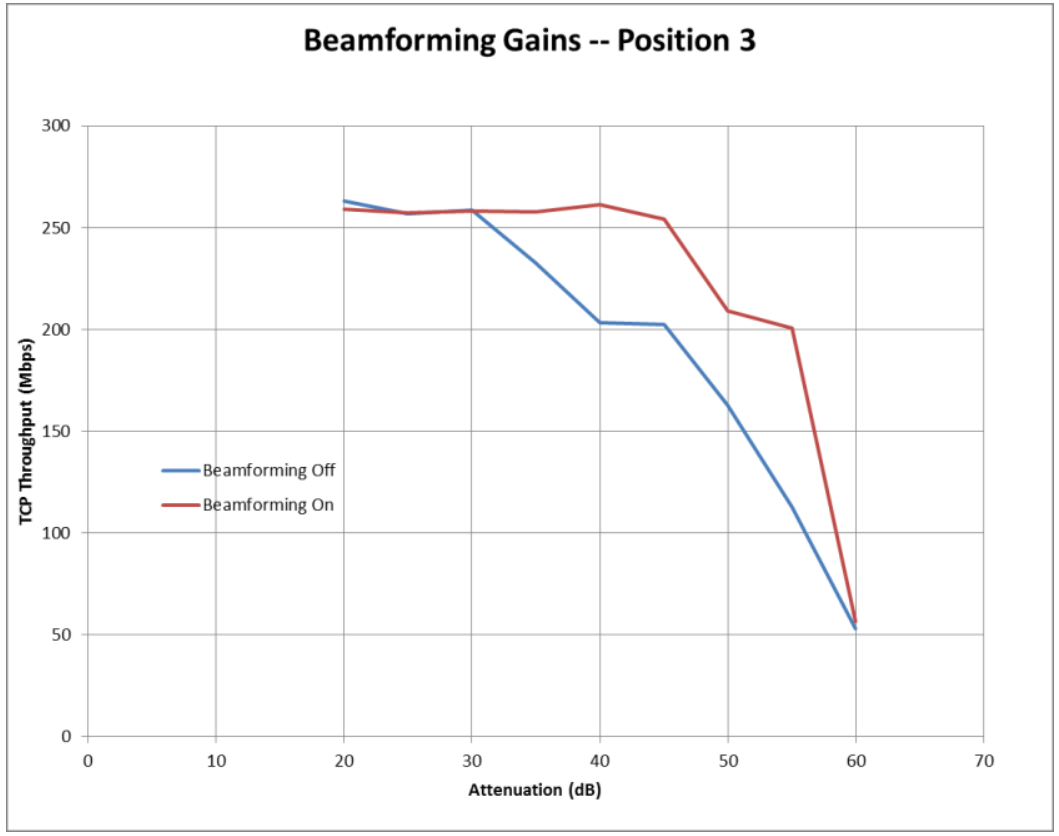
Support for MU-MIMO and Beamforming

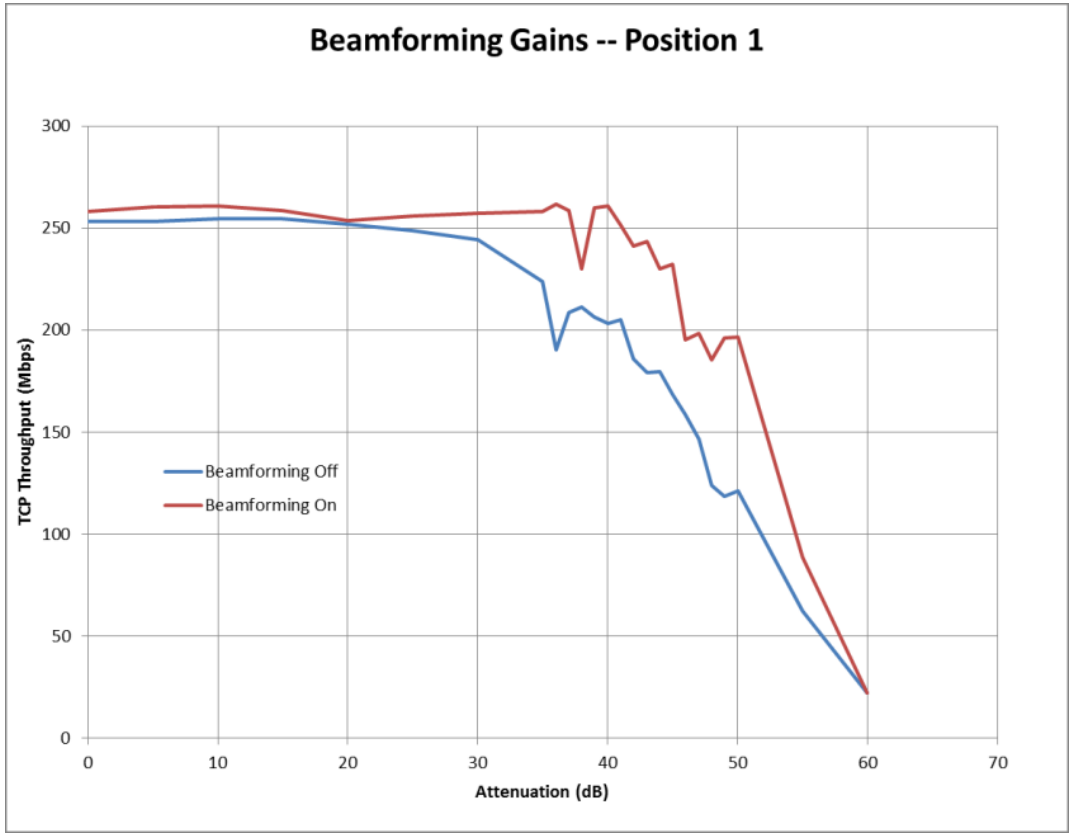


802.11 MU-MIMO beamforming techniques enable stations to transmit simultaneously in the same airlink and on the same channel frequency.

MU-MIMO = multi user multiple input multiple output

Beamforming Gains

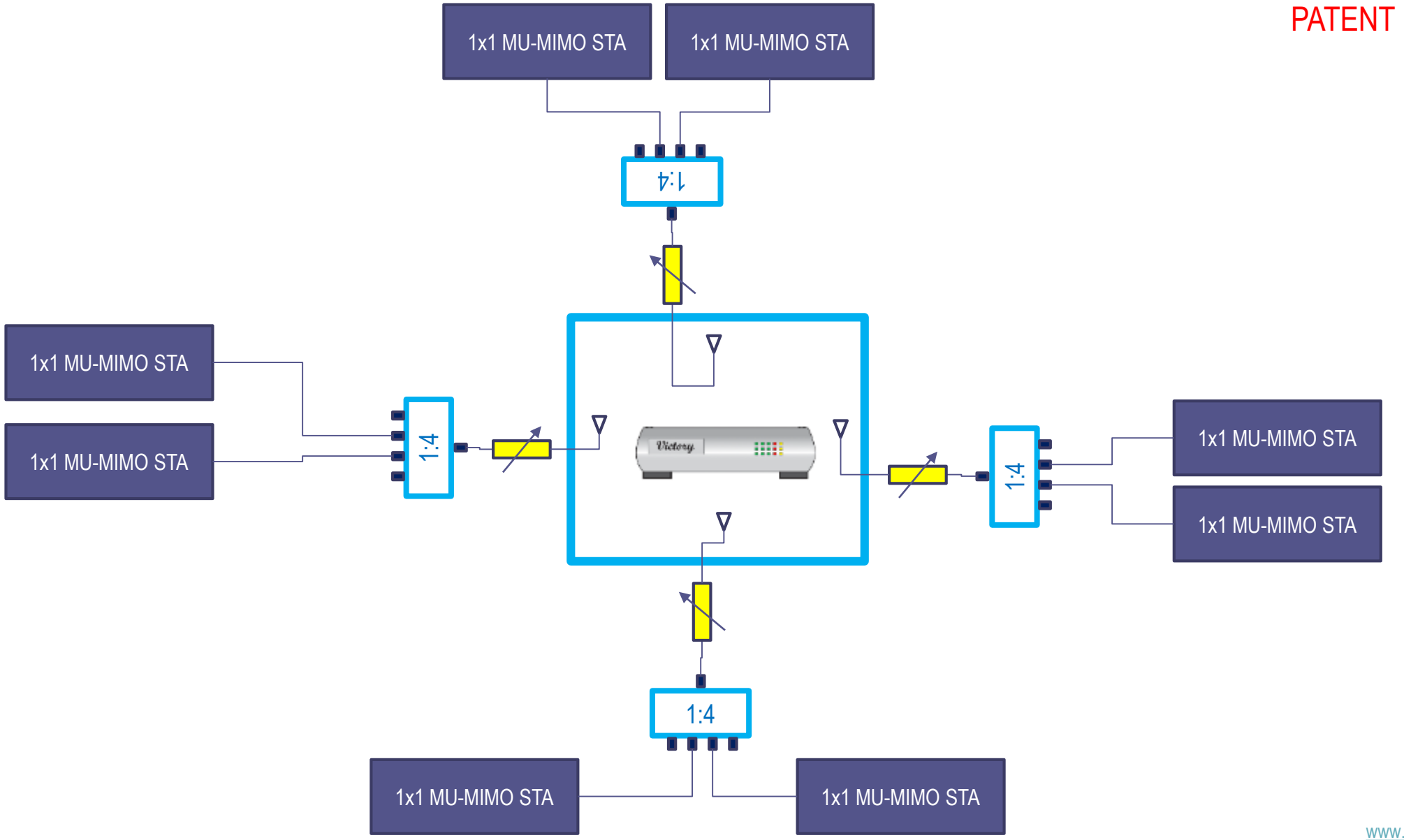




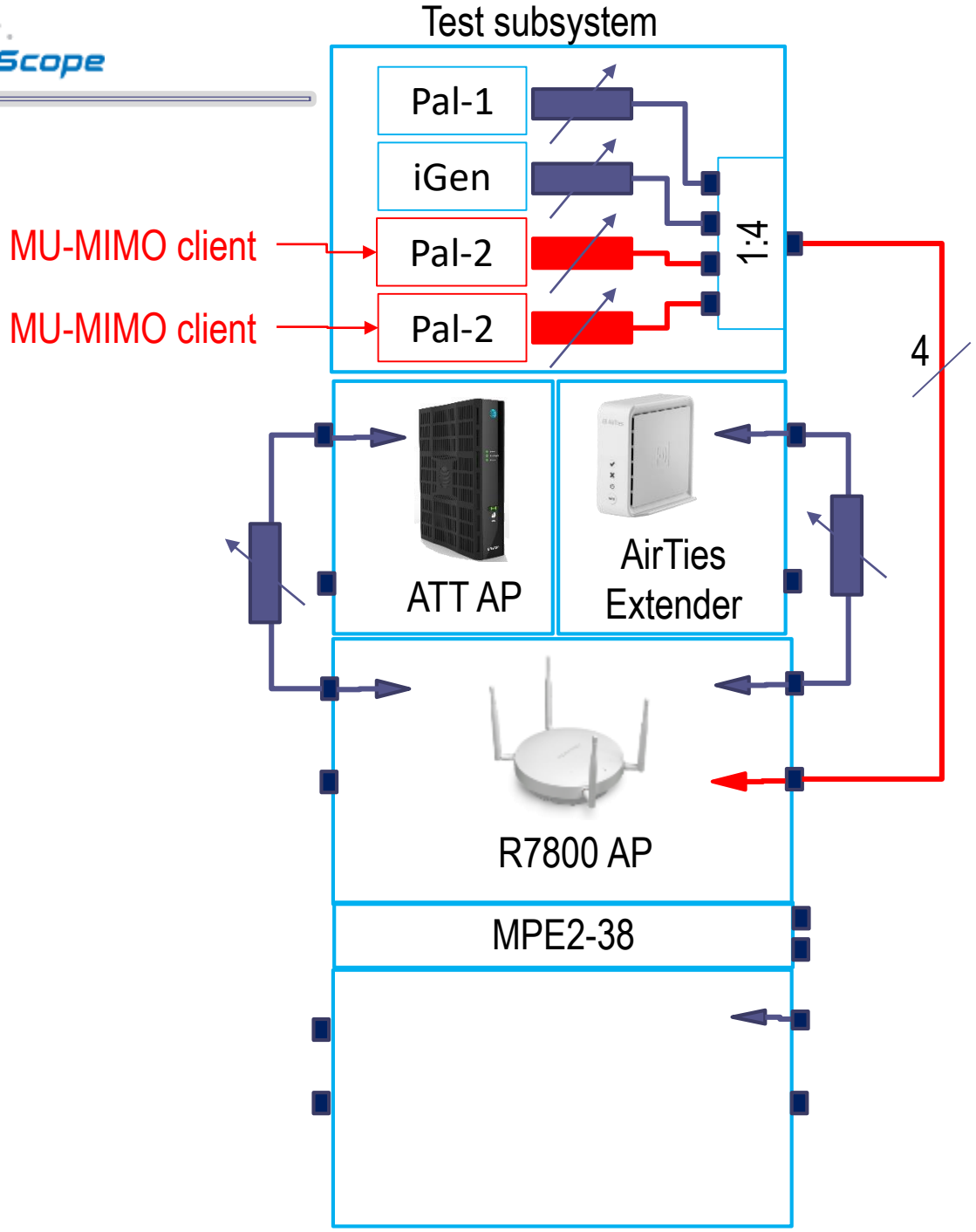
Both positions showing beamforming gain

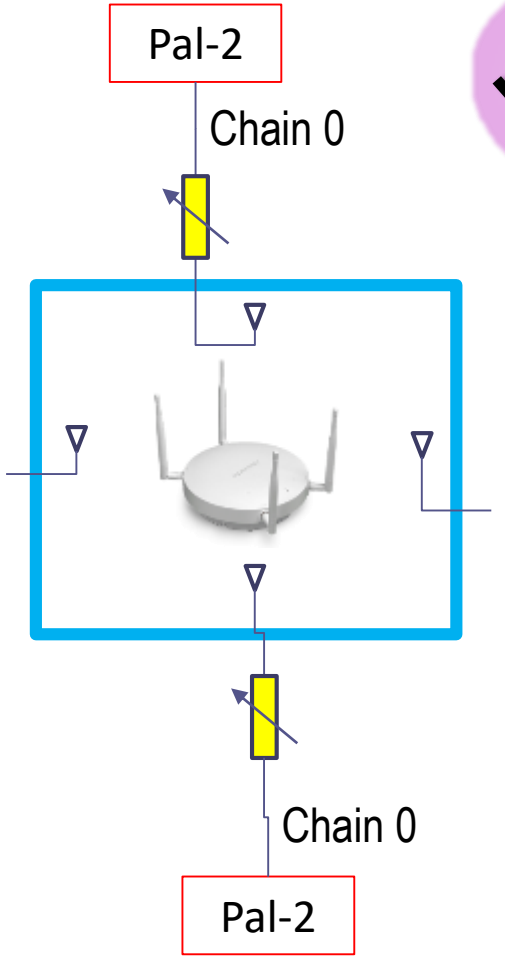
MU-MIMO with Controllable Correlation

PATENT PENDING



Demo of *MU-MIMO* Test





Live demo

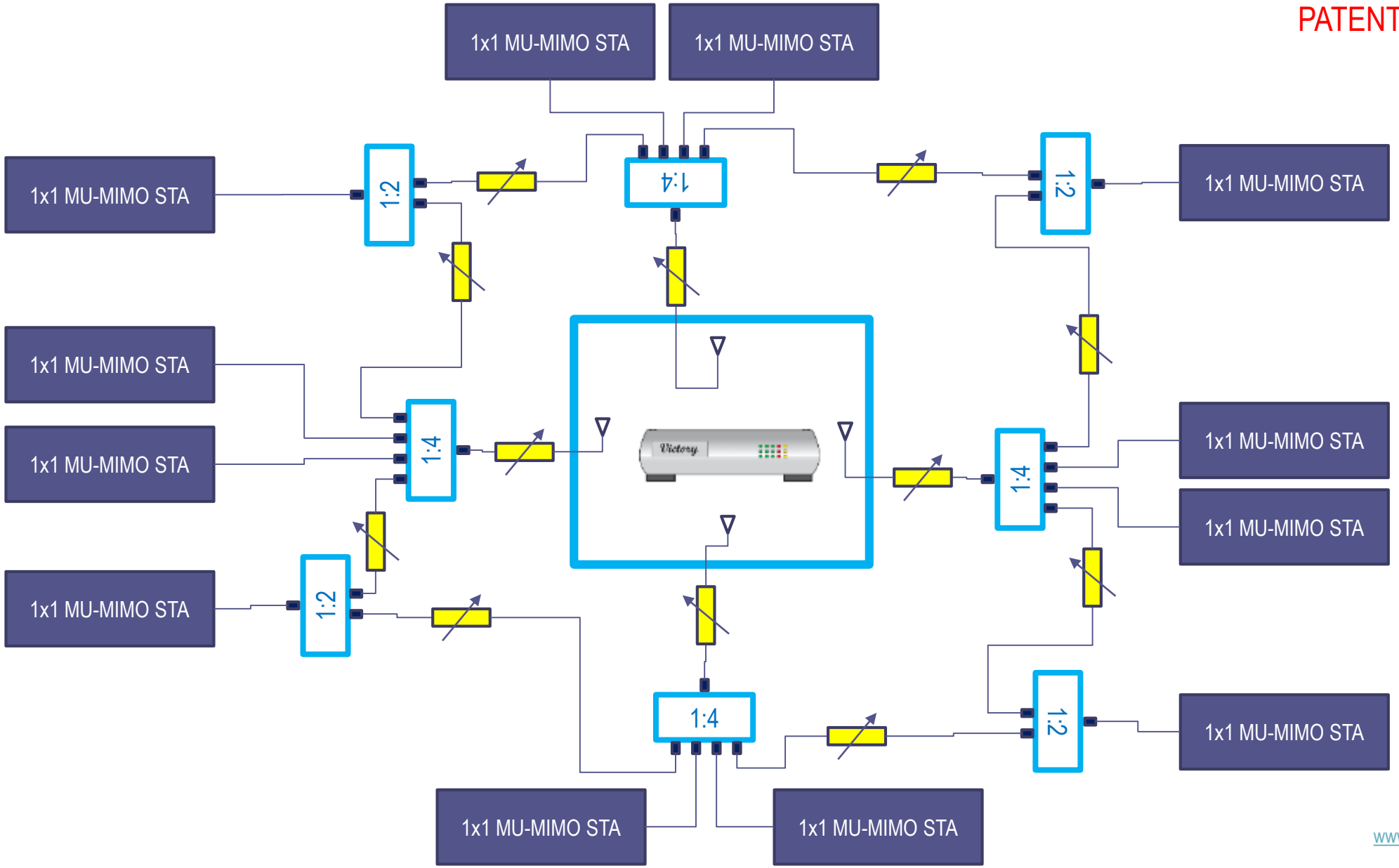
MU-MIMO on
524 Mbps

MU-MIMO off
271 Mbps

MU-MIMO gain
1.93

MU-MIMO with Controllable Correlation

PATENT PENDING



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Short break

- Band steering / Load balancing
- Coexistence
- IEEE recommended test practices

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Mesh / Extender Products on the Market

Nest Cam

eero

Google

Luma

Netgear

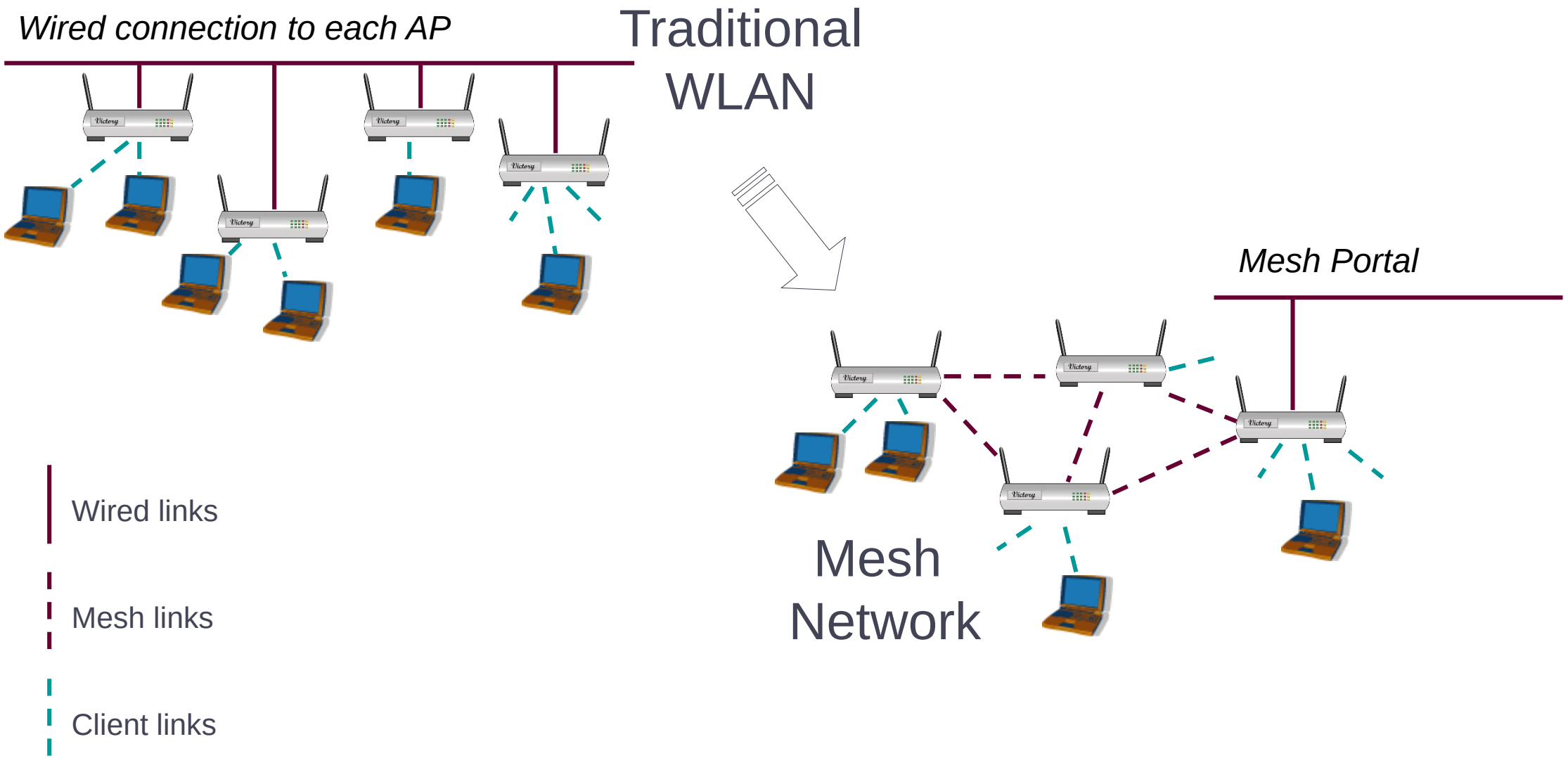
AmpliFi

TP-Link

Linksys

AirTies

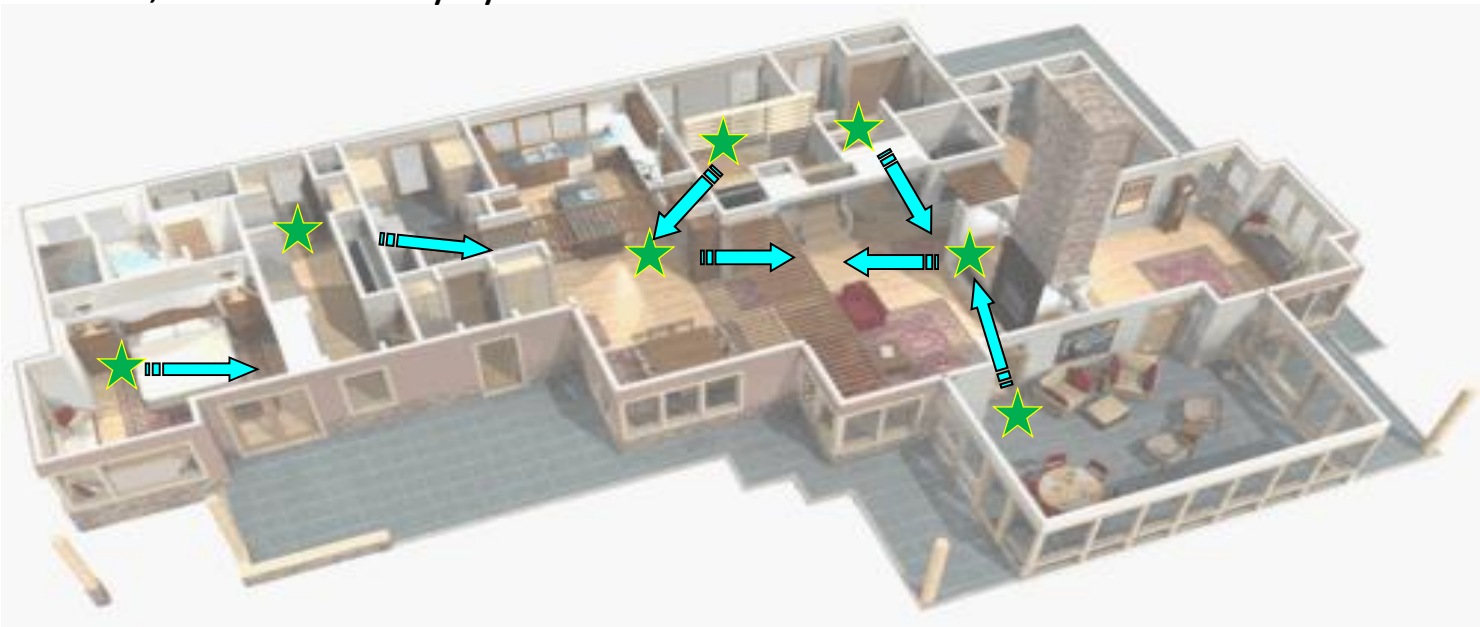
Traditional vs. Mesh Architecture



IoT (Internet of Things)

Wireless connectivity of sensors and controls

Markets: smart metering, industrial controls, building automation networks, medical devices, home security systems

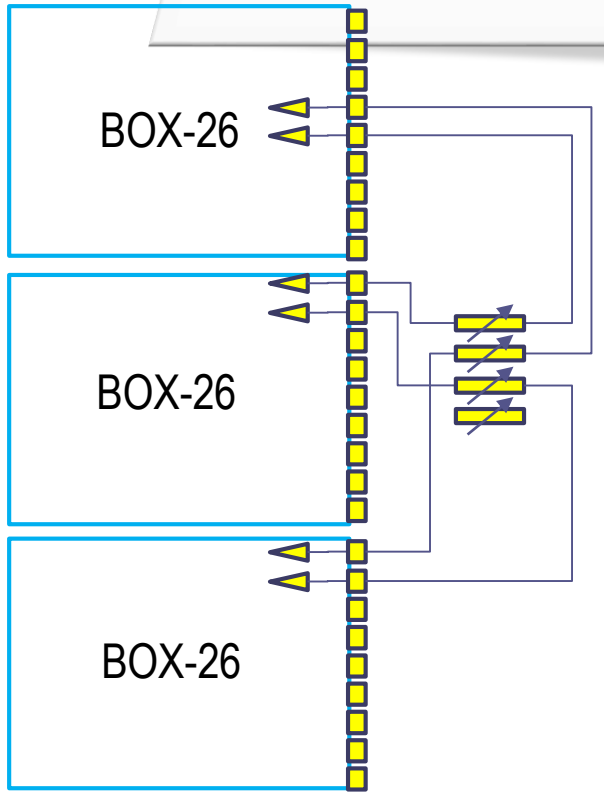


Air conditioning controls
CO alarms
Heat alarms
Automotive HVAC controls
Time controls
Thermostats
Zone controls
Electronic ignition control
Gas controls
Motor speed controls
Smoke alarm
Reversing valves
Defrost controls
Change over thermostat
Pressure control

octoScope

Controlled RF Environment Hardware
(OPTIONAL for Members; required for Authorized Test Labs)

Item	Vendor	Part #	Quantity	Price (each)
octoBox Shielded RF Chamber	Octoscope	OB-26X-SILVER	3	Contact Octoscope for quote info@octoscope.com +1.978.222.3114
octoBox stack base with casters	Octoscope	OB-26-BASE	1	
octoBox Quad Attenuator	Octoscope	OB-quadAtten	1	

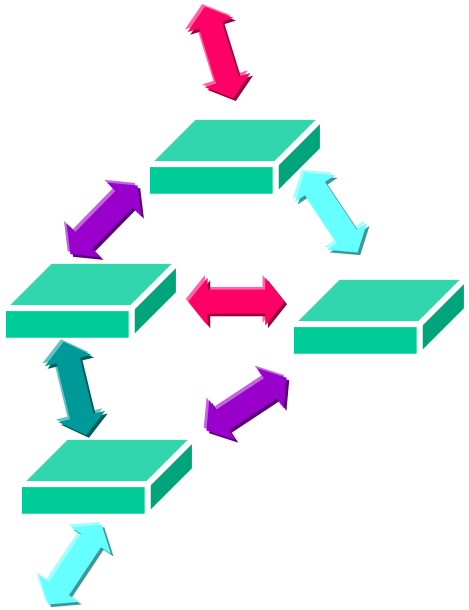


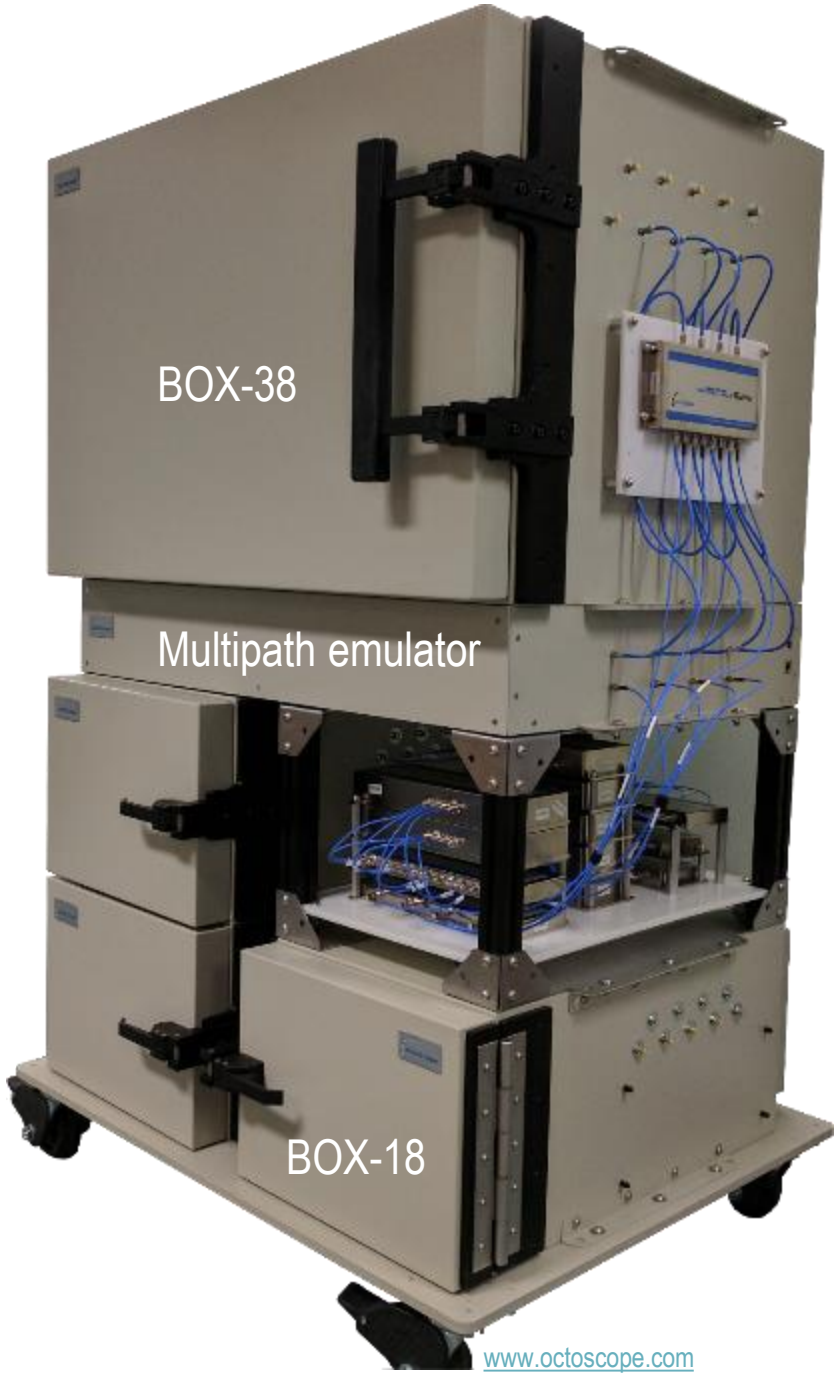
THREAD GROUP

Mesh Operation

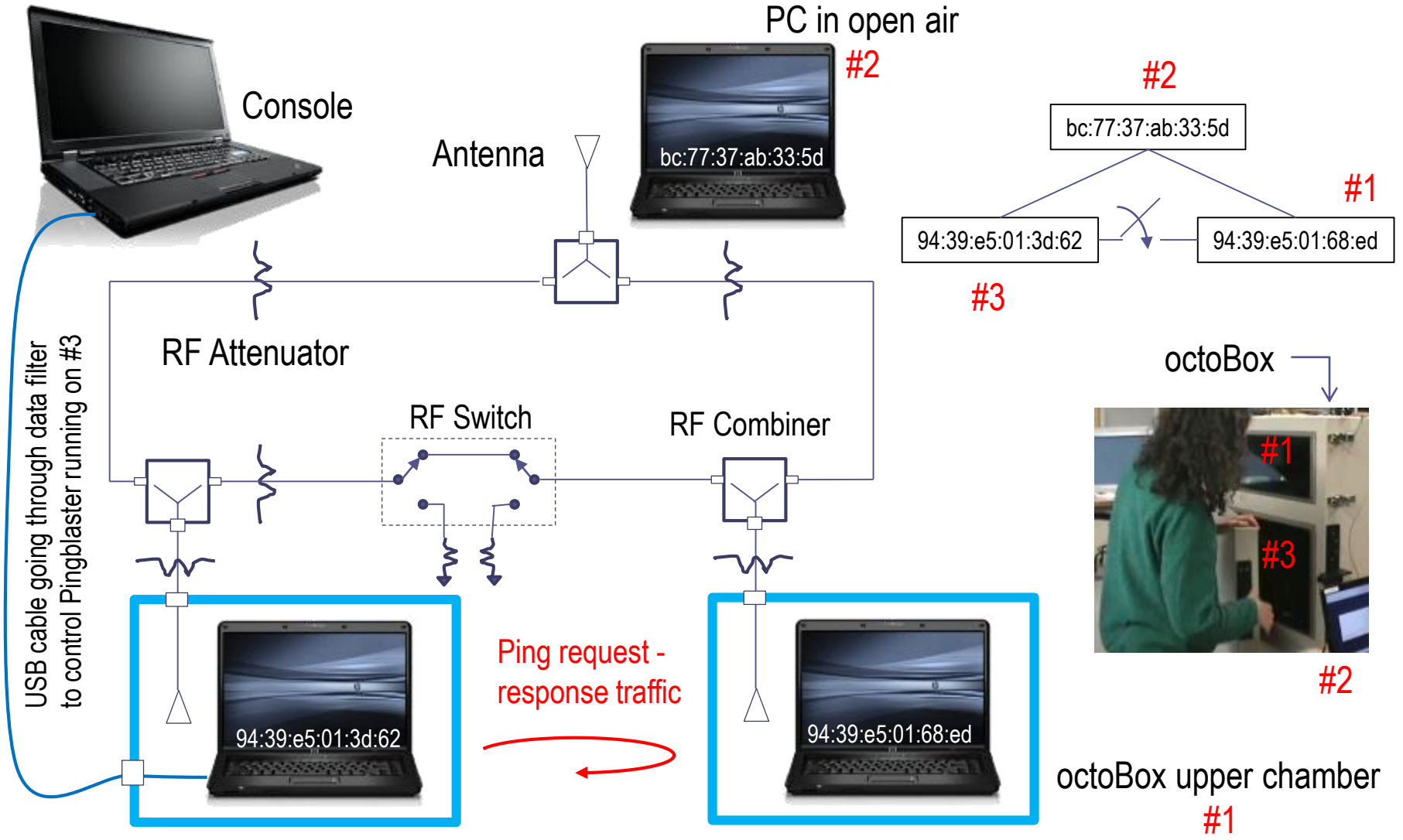
Measure

- Self-healing, self-forming
- Throughput, QoS vs. *hops*
- Throughput, QoS vs. *range*
- Routing efficiency
- Dealing with interference
- Client roaming among the mesh nodes

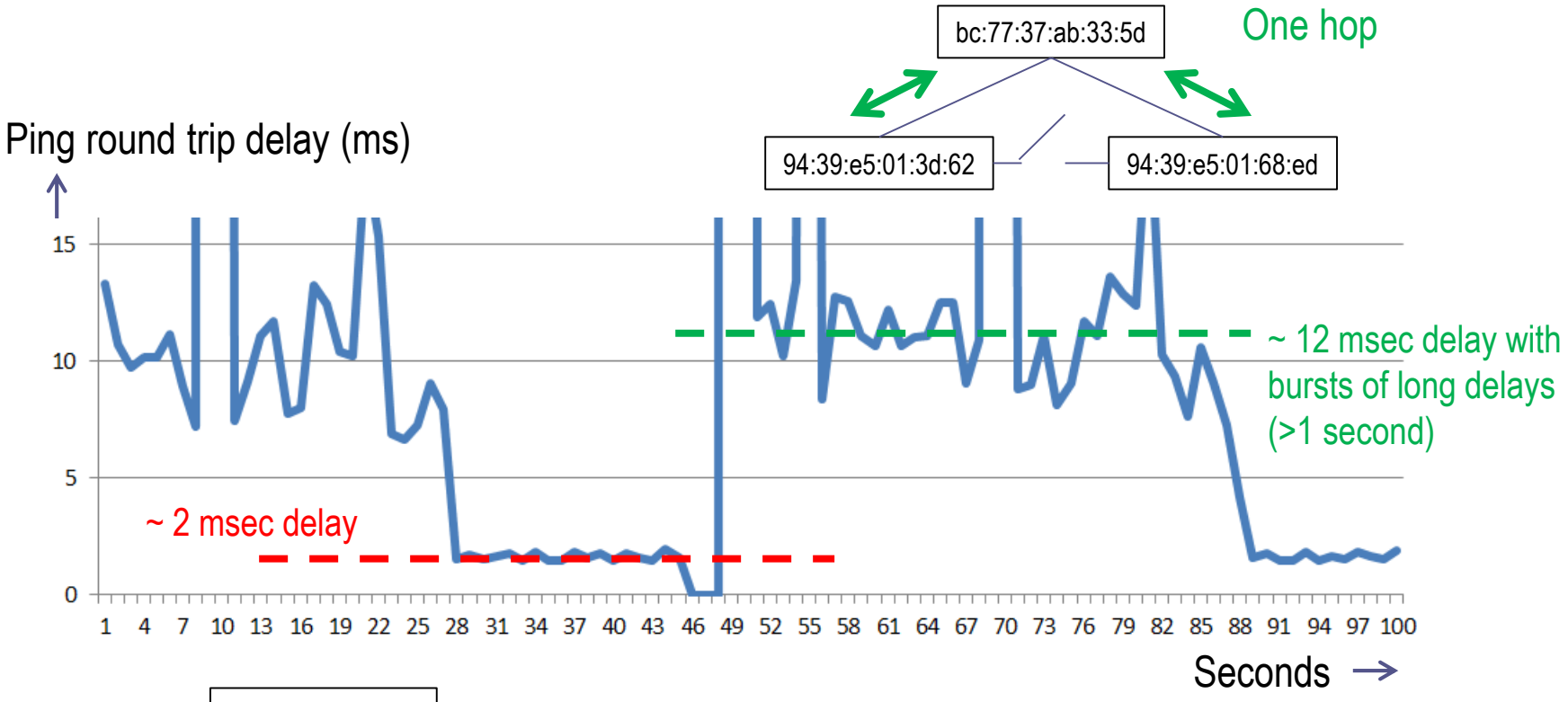


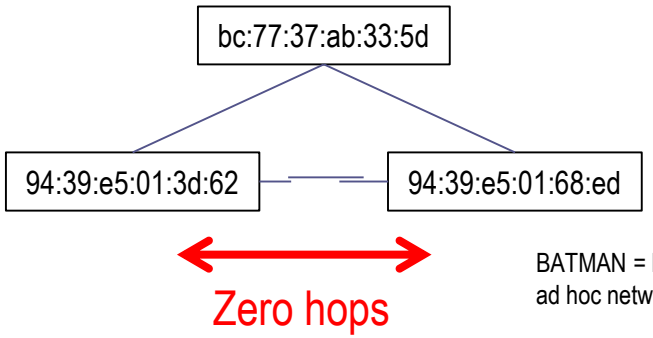


Example of a 3-Node Mesh Test



Ping Request to Response Delays Through the Mesh

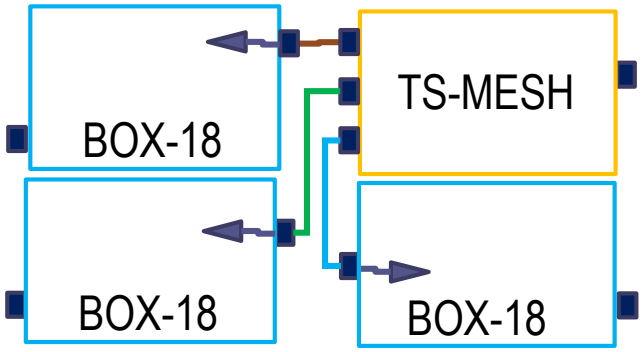


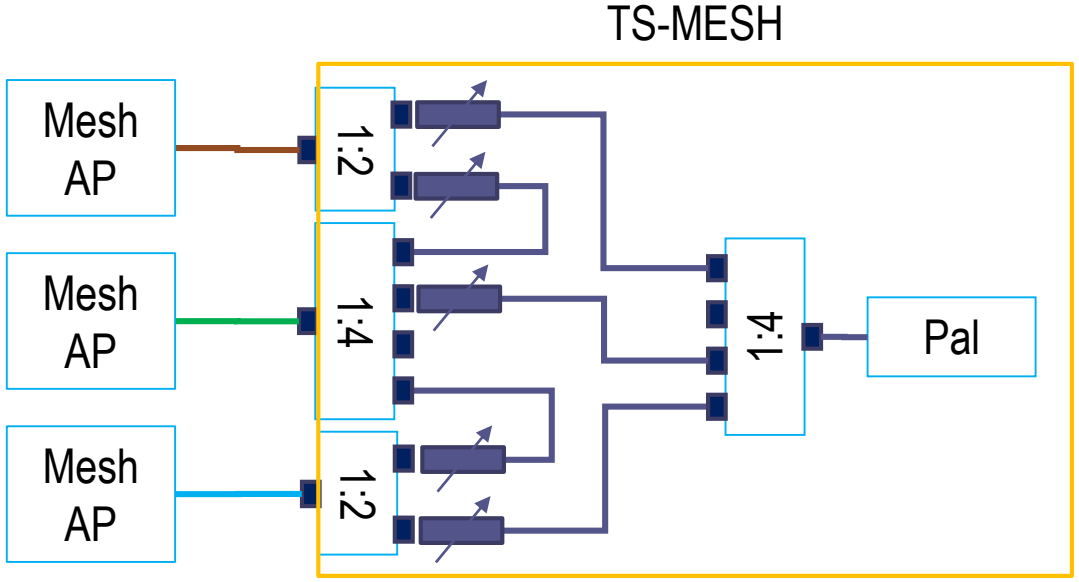


BATMAN = better approach to mobile ad hoc networking

Pingblaster application	BATMAN control app
BATMAN 2011.3.0 driver	
Linux kernel 2.6.38	
Linux Mint distribution v11	

3-Node Mesh Testbed with the Pal as a Roaming Client

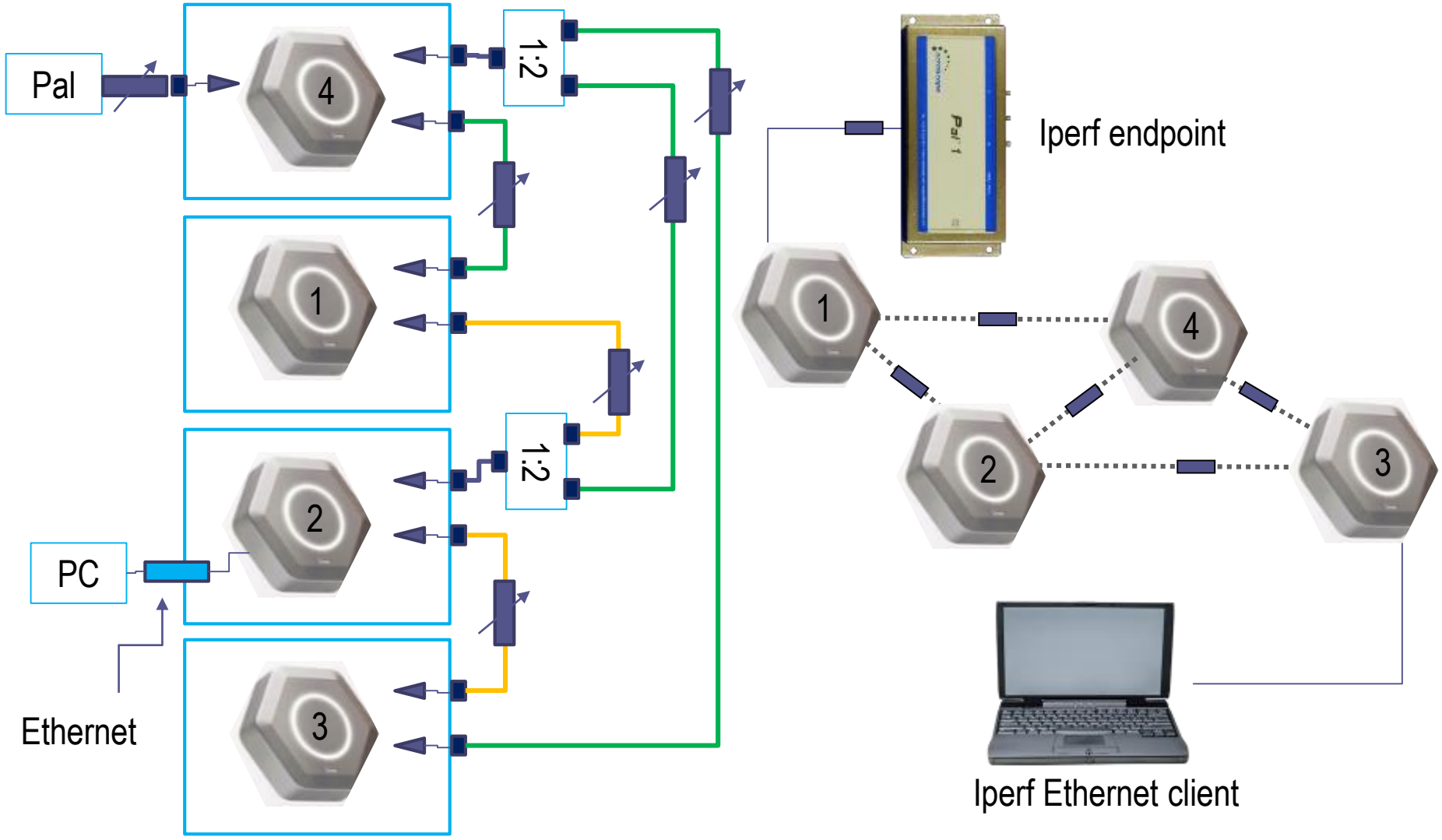


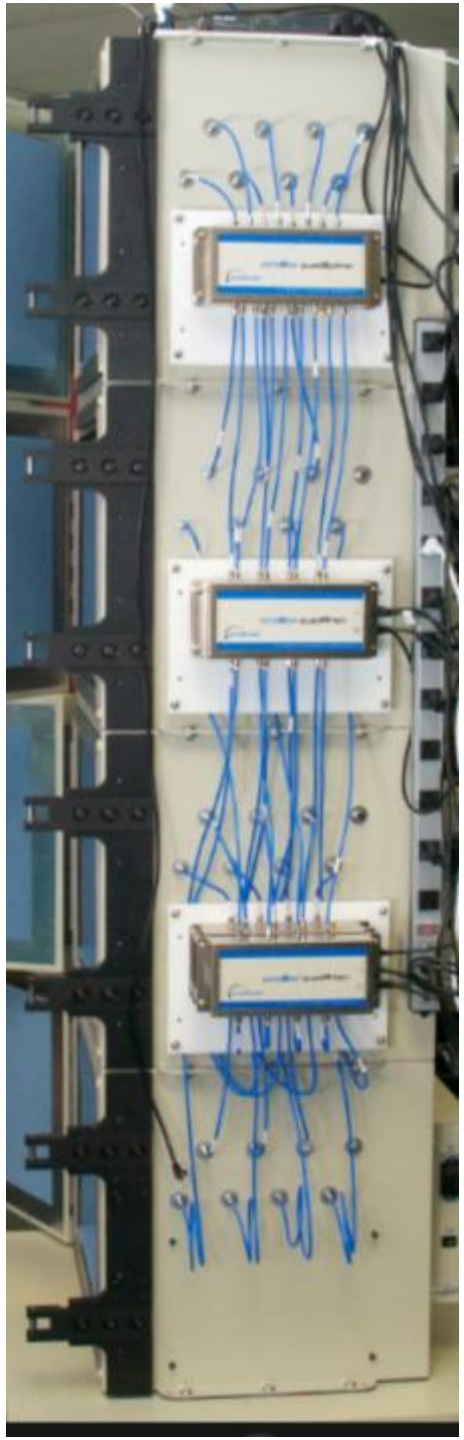


TS = test subsystem

Mesh Testbed Example

Throughput, roaming and mesh test cases





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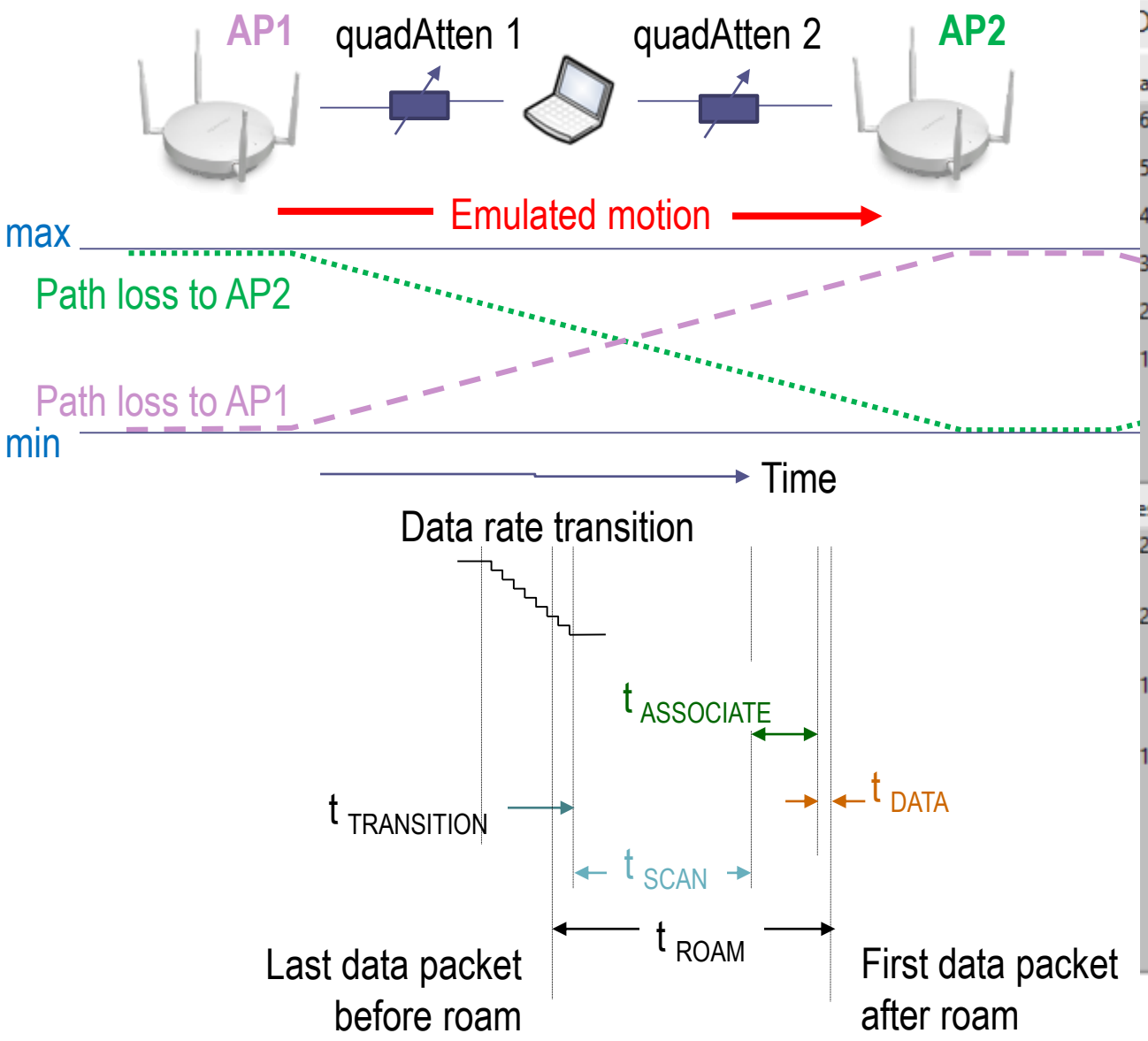
Short break

- Coexistence
- IEEE recommended test practices

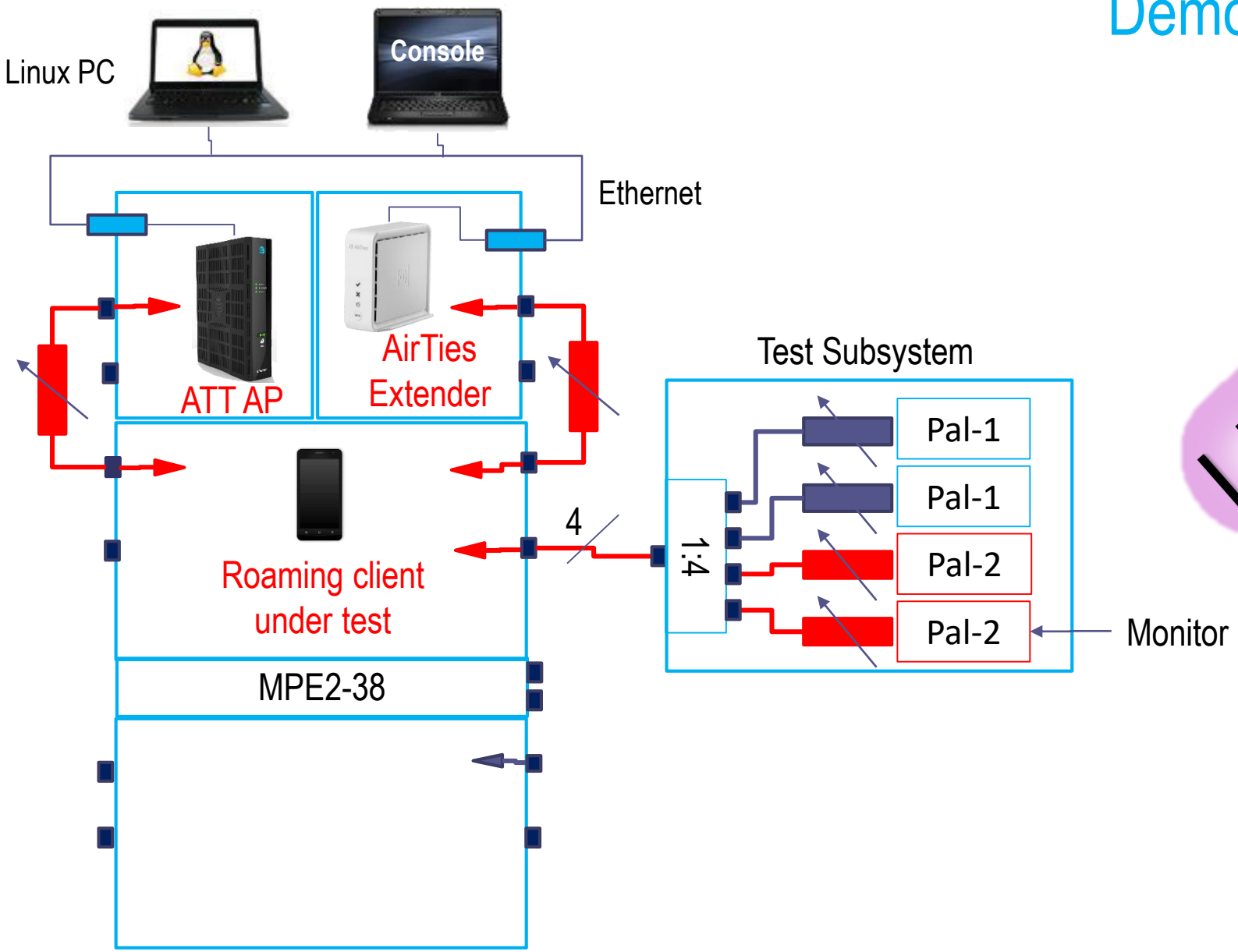
12:30 – 1:00 **Lunch**

1:00 **Live demonstrations, Q&A**

Roaming Test Conceptual Diagram



Demo of *Roaming*



Live demo

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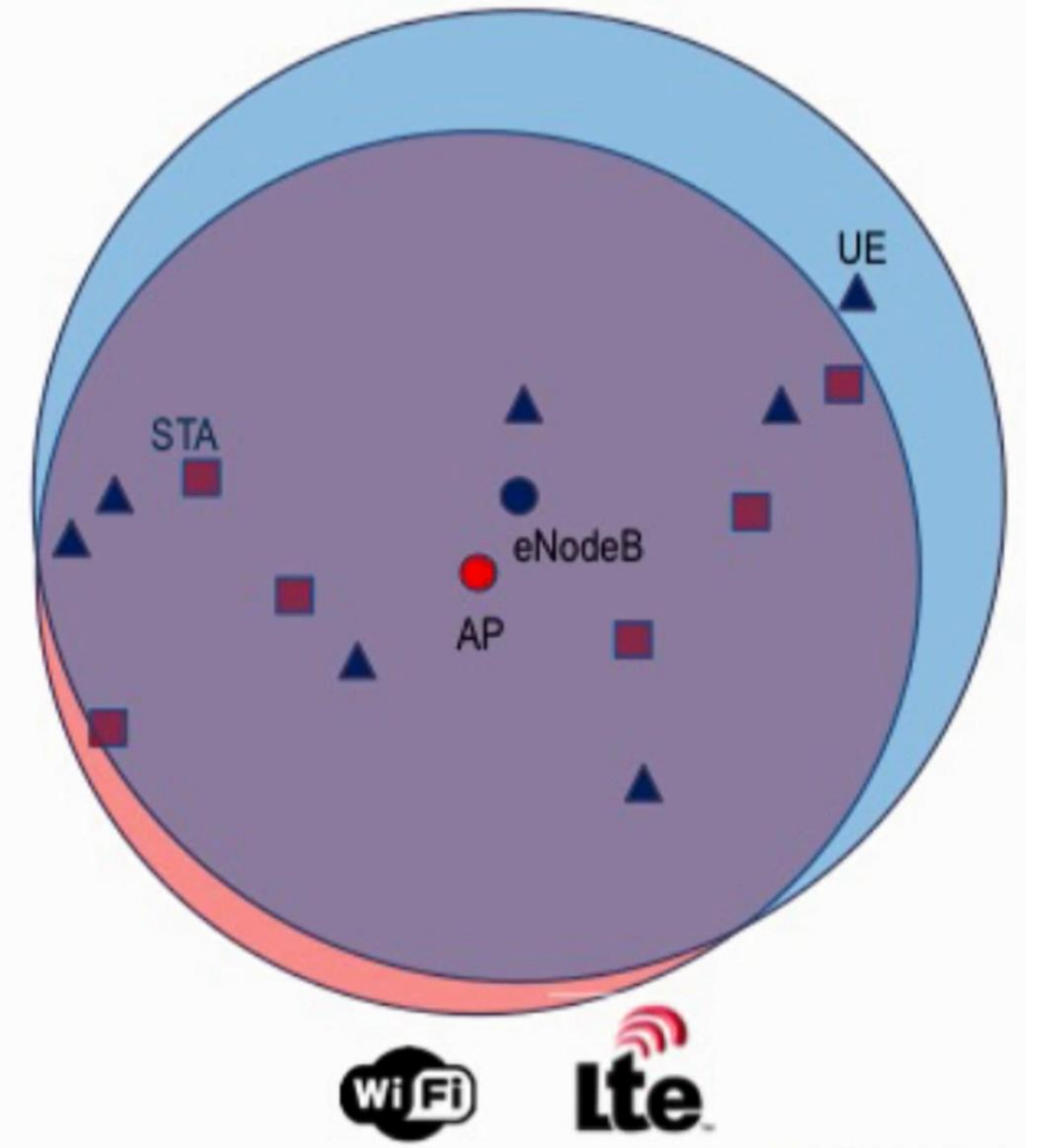
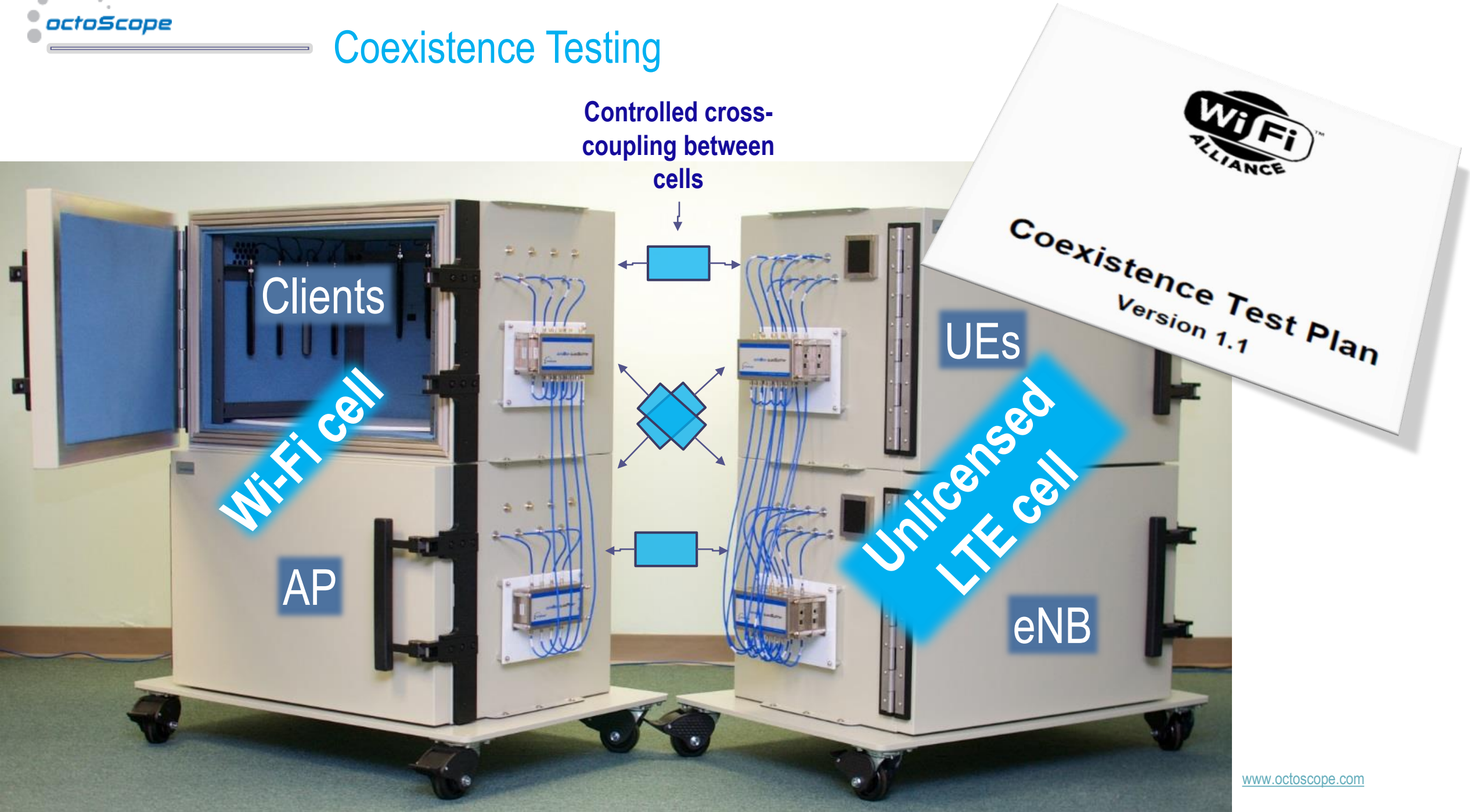
Coexistence of Key Wireless Technologies

Coexistence of Wi-Fi and unlicensed LTE in the 5 GHz band



Coexistence Testing



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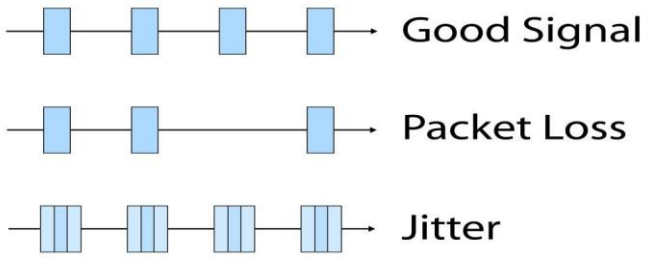
Voice over Wi-Fi Considerations

- Important to maintain isochronous nature of voice packet streams by controlling delay, jitter and packet loss
- Bursty packet loss due to
  - Roaming
  - Interference from LTE-U or LTE-LAA
- Power consumption – sleep modes
  - APSD (automatic power save delivery)
  - PSMP (power save multi-poll) protocol
- WFA WMM (wireless multi-media) prioritization protocol



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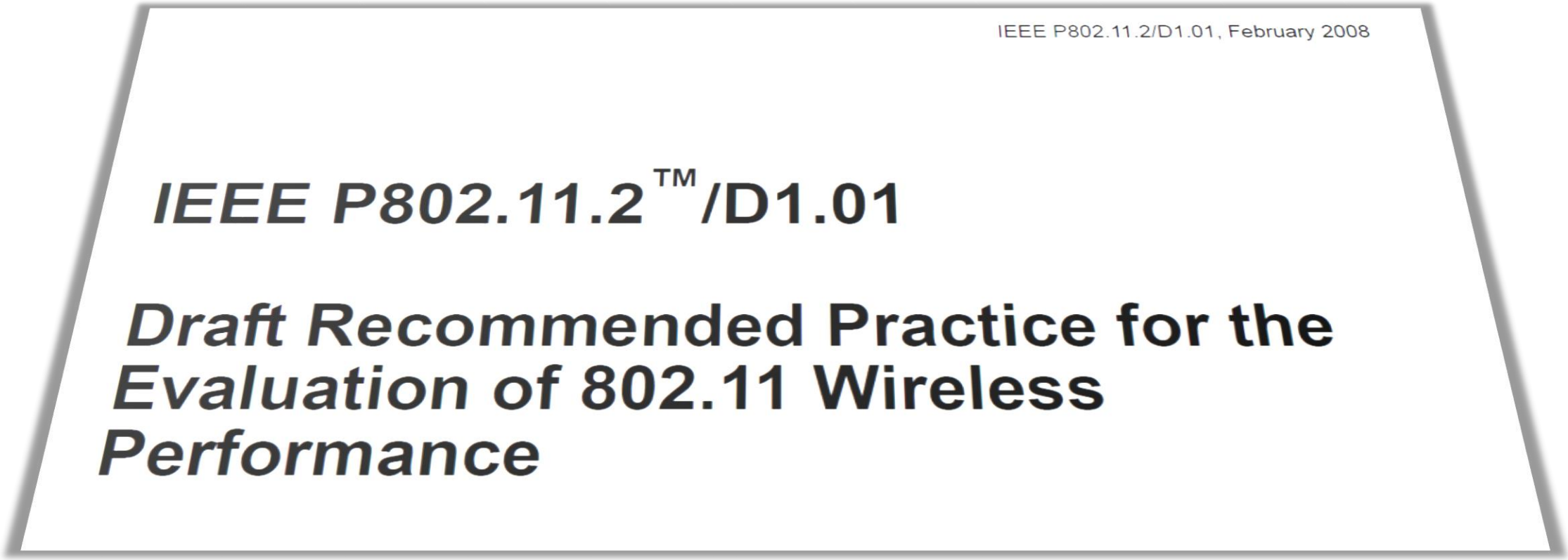
IEEE 802.11.2 Performance Test Specification

Defines test methods and metrics for evaluating performance of 802.11 devices and systems



Use Cases

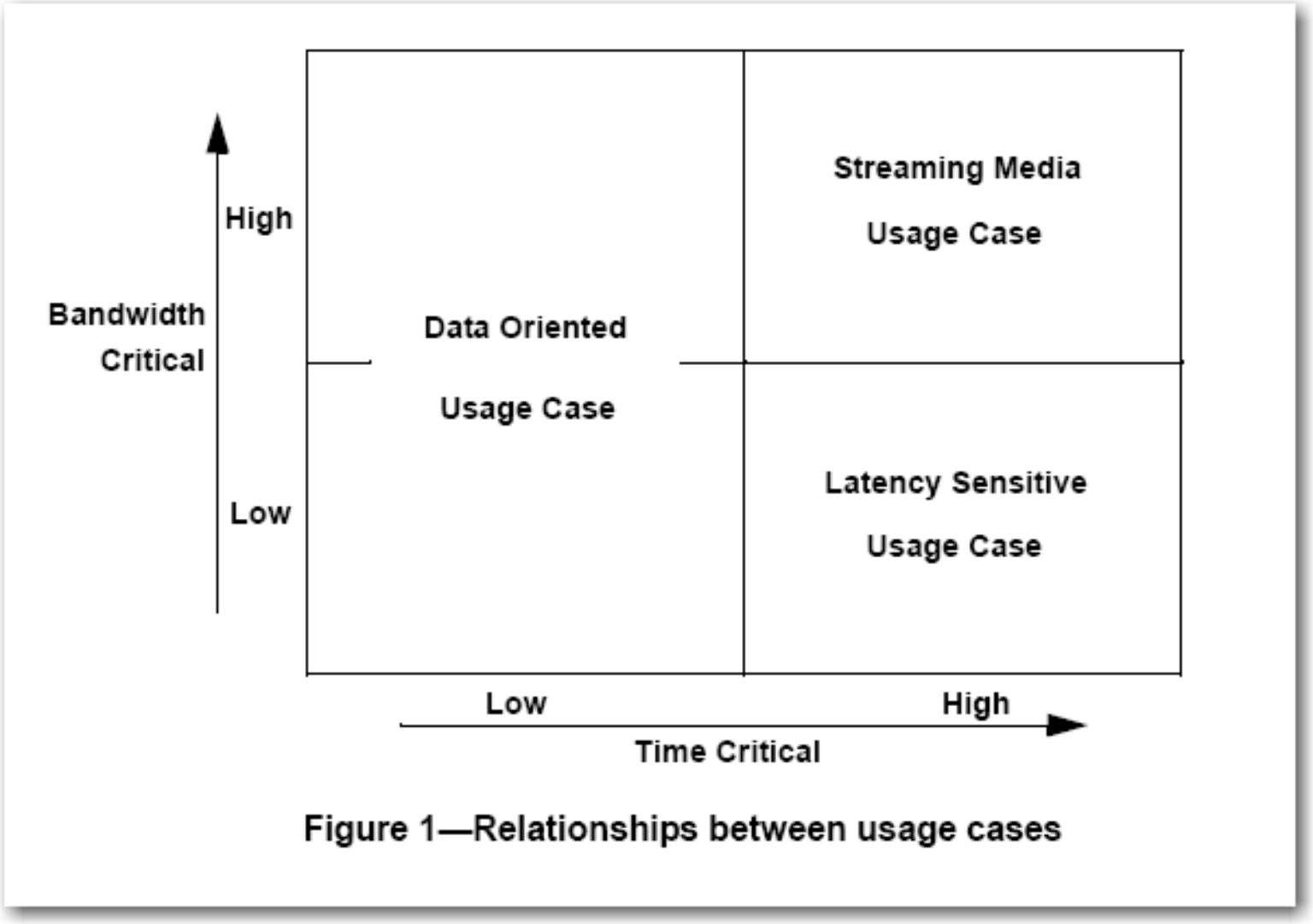


Figure 1—Relationships between usage cases

Example 802.11.2 Metrics

- Throughput: overall
- Throughput vs. range
- Throughput vs. attenuation (conducted and OTA)
- Throughput vs. receive power
- Transmit rate adaptation
- Antenna diversity
- Adjacent channel interference
- BSS transition time
- Fast BSS transition time
- Receiver sensitivity in a conducted environment
- Unicast intra-BSS throughput
- Unicast ESS throughput
- Multicast forwarding rate
- Endstation association rate
- Endstation database capacity
- Power consumption
- Coexistence of overlapping BSSs in an OTA environment
- Packet loss
- Latency
- Jitter
- Video performance

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Q & A

Thank you!