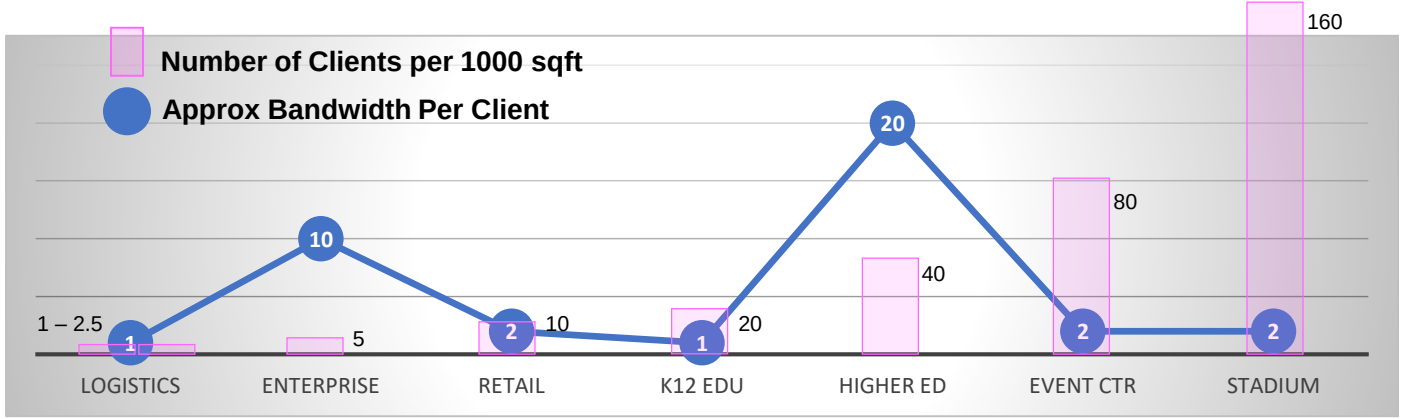
Connected in the Classroom - cnPilot Education Solutions

High Capacity = density of devices X required bitrate

- *capacity is the number of clients served by a single AP; and the data throughput required for each client and application*
- *Total network capacity also includes the total clients served by multiple access points. Issues such as co and adjacent channel interference must be factored*



Off the scale IOT, Ultra-High Density Mobile devices

Warehouse Logistics Enterprise Retail — *~ 1Mbps per device* — *~ 2 to 10Mbps per device*

Education — *~ 1 to 20Mbps per device*

Events Stadiums Airplanes — *~ 1 to 2Mbps per device*

Approximations to show relative client density and throughput. Some use cases can exceed what is shown

E-rate : US-FCC minimum Internet connectivity target

100Mbps per 1000 students

- not all students would be online at the same time
- not all applications would consume their max bitrate at the same time

As of 2017, 77% of US schools meet this standard, up from 30% in 2013

Category One

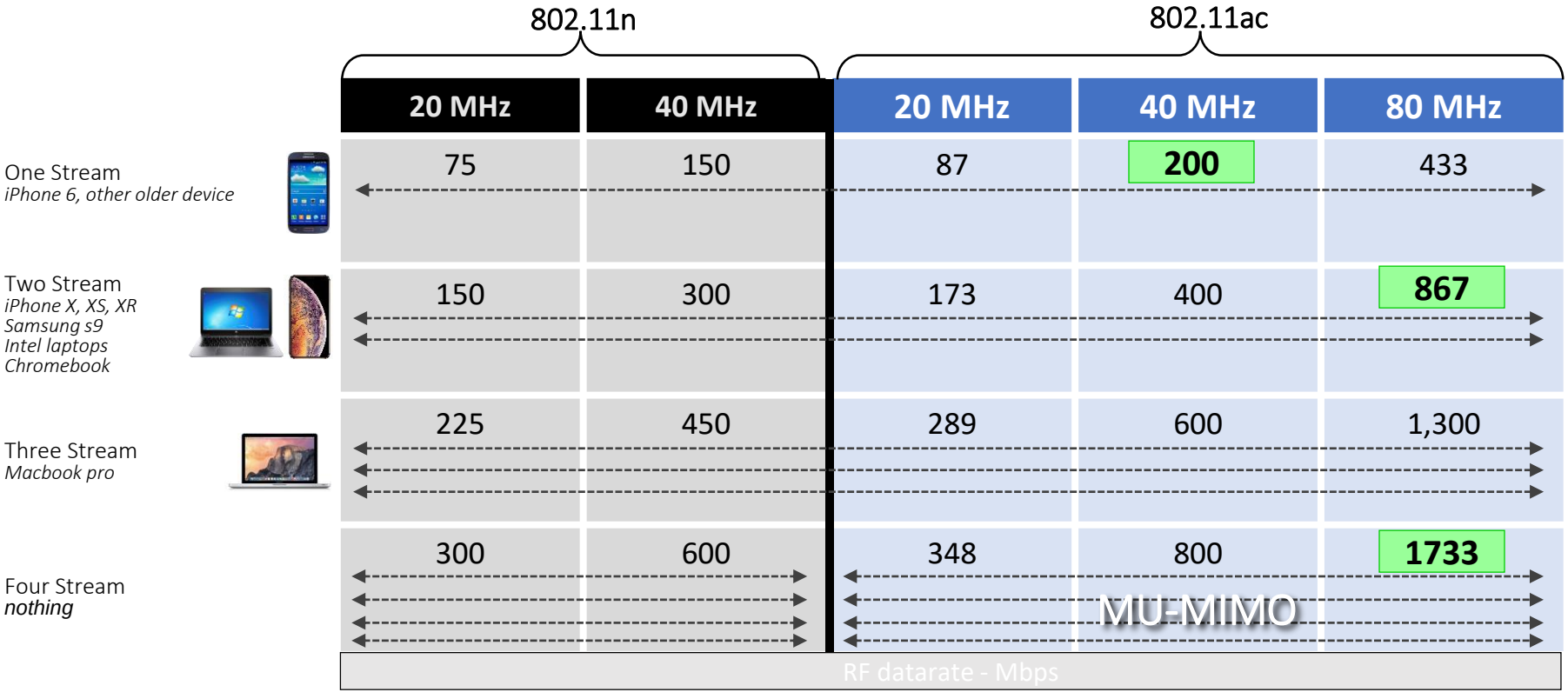
Telecommunications and Internet Access

Category Two

In-building infrastructure and wireless access

More Streams, Wider Channels

Cambium Networks™

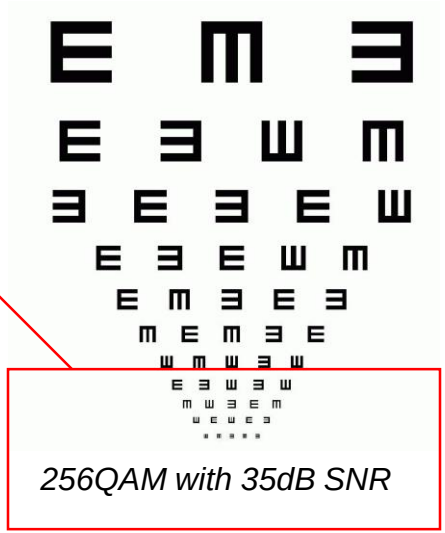


802.11AC Key Feature: 256QAM

The desired range for High Density is defined by the target -50 dBm RSSI

Design Requirement	Advantages
-50dBm RSSI (256QAM requires 35-40dB SNR)	33% faster speed than 11n Works with all 11AC clients (i.e. Samsung S5 was an early 11AC client)

Signal-to-Noise Ratio	1 dB	3 dB	5 dB	----------	35 dB
802.11b	None	1 Mbps	5.5 Mbps	----------	11 Mbps
802.11ag	None	6 Mbps	6 Mbps	----------	54 Mbps
802.11ac, 20MHz	None	None	14.4 Mbps	----------	173 Mbps
802.11ac, 40MHz	None	None	None	----------	400 Mbps



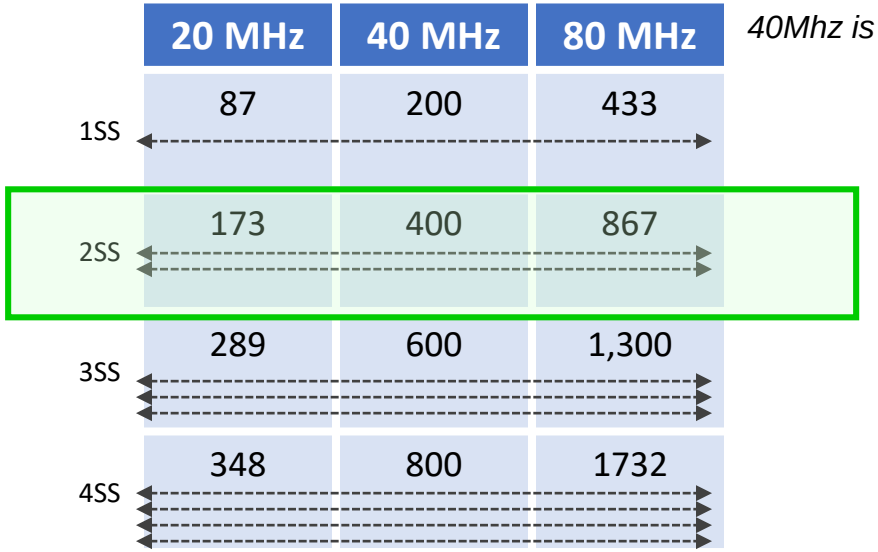
256QAM with 35dB SNR

Gotchas: since the AP is capable of sending packets at lower data rates; such as 802.11b and g; the AP can be "seen" a great distance from the target area. This is the "advertisement range" and must be controlled. Disable 11b entirely, and prune out 11g rates below 24Mbps

802.11AC Key Feature: Channel Bonding

Use up to 40MHz channels on the 5GHz band for the primary data network where High Density is desired

Design Requirement	Advantages
20MHz or 40MHz wide channels	2x faster than 11n at the same MCS rate Faster speeds means more clients can share the same network



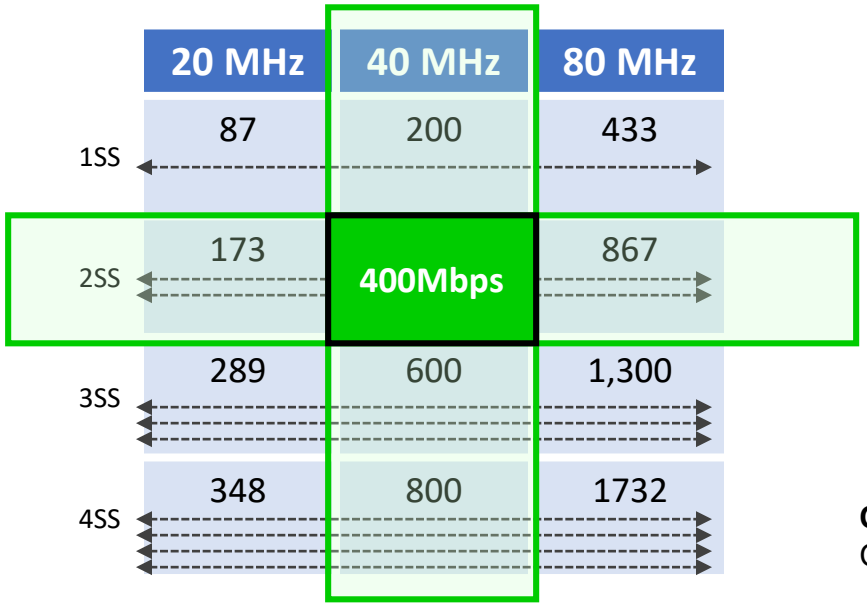
40Mhz is the most common client capability

Gotchas: In the US, there are 11 sets of 40Mhz channels – assuming that DFS channels are available in your area. If DFS channels are not available due to proximity with radar, you may have to use 20MHz channels. Other situations may also occur that dictate a 20MHz channel is required.

802.11AC Key Feature: Increased Spatial Streams

Two spatial streams is common for most laptops and high end smart phones

Design Requirement	Advantages
Primarily applies to indoor APs	Easy 2x speed multiplier



Best combination of client capabilities

2SS (2 spatial streams)
40MHz channels
256 QAM

Gotchas: requires MIMO for effective spatial stream combining. Outdoor networks require polar diversity antennas

Access Point Matrix

No one size fits all – choose the right access point for the desired outcome

	E600 4x4 dual radio	E410 2x2 dual radio	E430 2x2 Wallplate	E500 Omni Outdoor	E501 30º Sector Outdoor	E502 120º Sector Outdoor
Classroom/Lecture Hall	Yes					
Skills training / ROTC / music	Maybe	Yes				
Dorm Room	Maybe	Yes	Yes			
Outdoor zones / campus				Yes		yes
Stadium	e600			Yes	Yes	Yes

Bring it all together with network management

Cambium Networks™

e430
Wallplate AP, 11ac wave 2, 2x2
Ideal for: dorm rooms, micro-cell wifi

e410
11ac wave 2, ceiling mount, 2x2 dual radio
Ideal for: dorm rooms, some classrooms, general WiFi

e600
11ac, wave 2, integrated BLE 4x4
Ideal for: high density classroom, event

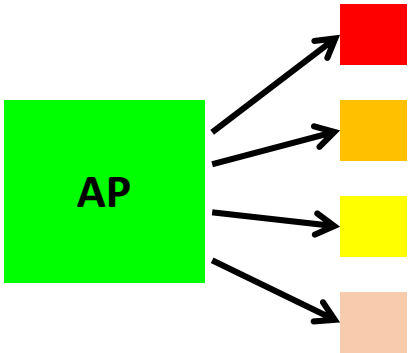
e500/e501/e502/e700
Outdoor IP67, 11ac wave 2, 2x2 or 4x4
Ideal for: Outdoor, stadium

backup

802.11AC Key Feature: DL Multi-User MIMO

Increase network capacity by ~ 2.5x using DownLink Multi-User MIMO

Design Requirement	Advantages
Requires high SNR and supported clients	2.5x capacity multiplier by transmitting to multiple clients at the same time



Theoretically, MU-MIMO will transmit up to 200Mbps (40MHz, 1SS) to each of four wireless clients at the same time. Or;

Transmit up to 400Mbps (40MHz, 2SS) to each of two wireless clients

Backward compatible with legacy 11n and other 11AC clients

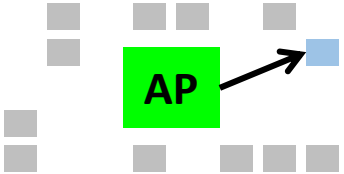
Gotchas: works best with stationary clients

802.11AC MU-MIMO: Multiply Capacity for High Density

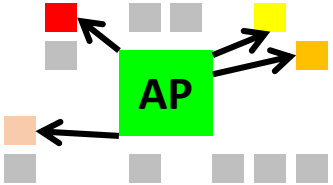
Automatic selection of best transmission clients to maximize aggregate throughput

Single User (SU)

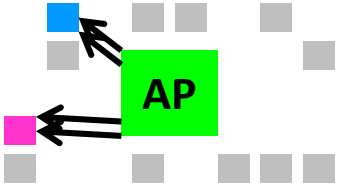
Used for management frames, 11n and 11ac clients



Multi User (MU): 4 * 1x1



Multi User (MU): 2 * 2x2



Upstream packets from the client to the AP are Single User mode. Failures in the algorithm, or protocols or environment will reduce effective MU-MIMO throughput

For each transmit opportunity, the access point can do one of three things;

1. Transmit multiple streams to multiple clients
2. Transmit single user (SU) management packets
3. Transmit single user mode for 802.11AC wave 1 clients or 11n clients

DownLink MU-MIMO – basically how it works

Cambium Networks™

1. Uses Transmit Beamforming (part of 802.11ac standard)

2. Each client sends Channel State Information (CSI) to the AP
   - CSI is the signal and noise level of each sub-carrier

3. The AP builds a steering matrix to decide which clients can be grouped

4. For each transmission; the AP transmits either
   - Multiple coded streams to clients that support MU-MIMO
   - Single stream to all other clients

5. Limitations
   - Downstream ONLY
   - Only applies to some data packets; all management packets are Single Stream

Pros and Cons

Cambium Networks™

PRO

Can increase the total aggregate speed from 50% to 250%

Works well for clients not in motion – e.g. a school classroom

CON

Downstream is MU; Upstream is still SU

Time to calculate the steering matrix too long for mobile clients e.g. a Trade Show

- As the client moves, the CSI changes, so the steering matrix has to be re-calculated

In very high density, the location of the clients are too close to determine a steering matrix e.g. clients on an airplane 10cm apart; 10m from the AP