How to Design a High-Density Network

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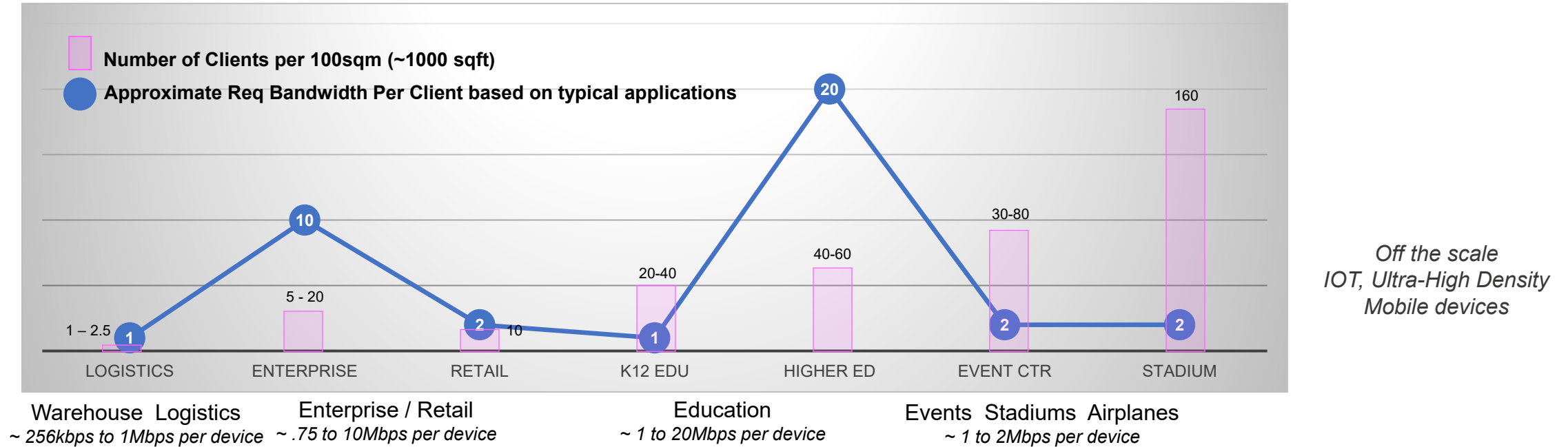Principal Solution Architect

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Where can we find high density networks?

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Definitions:
a high-density wireless network provides pervasive connectivity for all devices within a defined space

capacity is the number of clients served by a single AP; and the data throughput required for the client application

□ **Number of Clients per 100sqm (~1000 sqft)**

● **Approximate Req Bandwidth Per Client based on typical applications**

Off the scale
IOT, Ultra-High Density
Mobile devices

LOGISTICS	ENTERPRISE	RETAIL	K12 EDU	HIGHER ED	EVENT CTR	STADIUM
1 – 2.5	5 - 20	10	20-40	40-60	30-80	160
1	10	2	1	20	2	2

Warehouse Logistics
~ 256kbps to 1Mbps per device

Enterprise / Retail
~ .75 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

Characteristics of a well operating high-density network:

1. Low packet retransmissions rate

2. Low packet latency and jitter (1-2ms)

3. Balanced uplink / downlink datarates within the cell

Three keys to consider with a high-density network:

1. Throughput required to meet the application(s)

2. Survey and design for high SNR

3. Configure the APs for high density

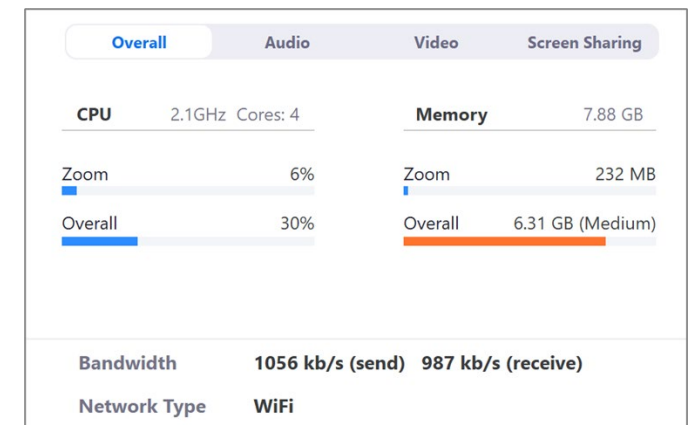# Know the applications that clients will use

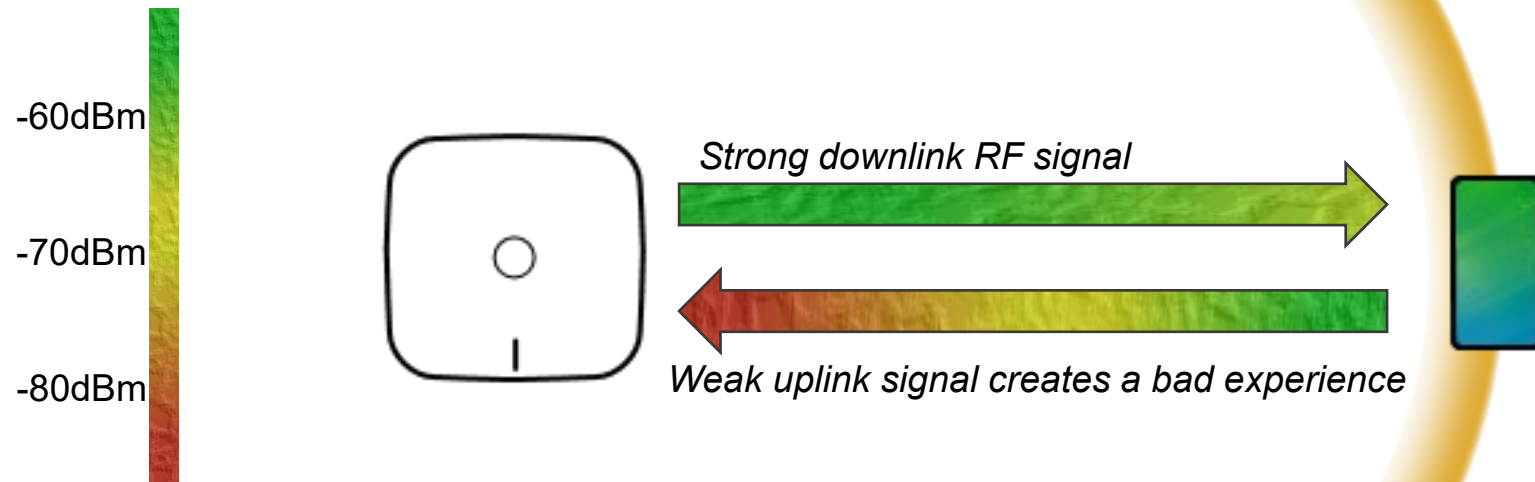| Application	Bitrate	Notes
Streaming Video	750kbps – 15Mbps	K12 online applications use low bitrate video window, higher education may use 4k full screen
Video Conferencing	750kbps – 2Mbps	Default video mode is 360p 12-25fps. Quality can be set up to 720p and higher frame rate
General Web Browsing	500kbps avg	Web browsing is bursty, low average bitrate, highly multiplexed due to browsing behaviour
Voice calls	96kbps	For common voice codecs

Tip:

All network traffic is multiplexed, so you cannot use simple math.

Must account for bursty traffic patterns and usage patterns.

TTL BW does not = Application BW * Number of Client

Zoom call statistics @ 360p, 24fps

Overall	Audio	Video	Screen Sharing

CPU	2.1GHz Cores: 4		Memory	7.88 GB
Zoom	6%		Zoom	232 MB
Overall	30%		Overall	6.31 GB (Medium)

Bandwidth	1056 kb/s (send) 987 kb/s (receive)
Network Type	WiFi

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Typical AP is 6x more powerful than typical smart phone

-60dBm

-70dBm

-80dBm

Strong downlink RF signal

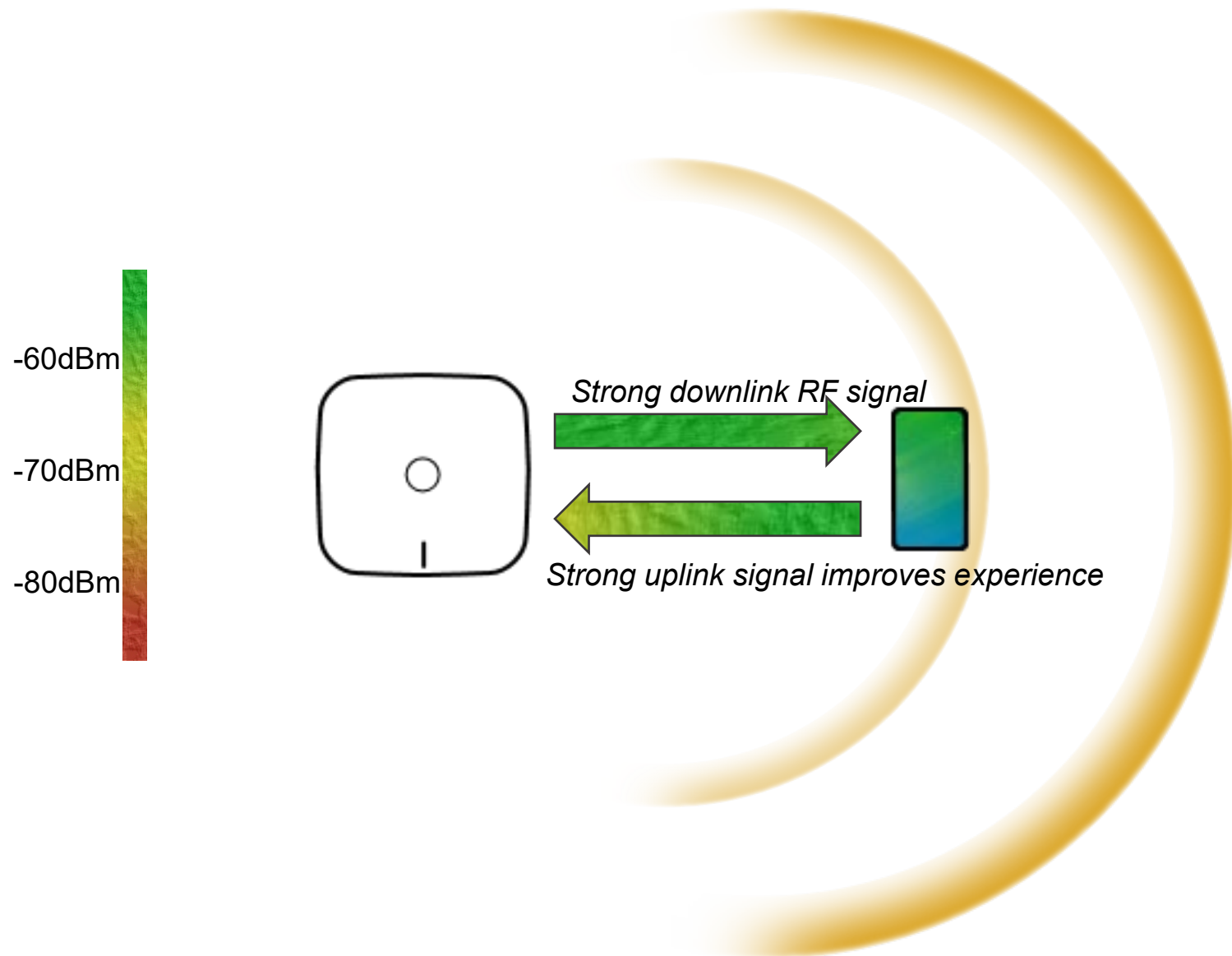*Weak uplink signal creates a bad experience*

Client at the edge of range

AP transmits more signal

Client can receive packets, but cannot respond to the AP

Result:
- Dropped connections
- Excessive client roaming
- Consume the battery
- Bad experience ☹

Design for Capacity

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-60dBm

-70dBm

-80dBm

Strong downlink RF signal

Strong uplink signal improves experience

Client within range

Reduce cell size by:

- Reduce AP transmit power
- Disable 802.11bg
- Prune low datarates

Expected Results:

- Lower packet latency
- Lower packet retry rate
- Consist rates across cells
- Higher capacity and density
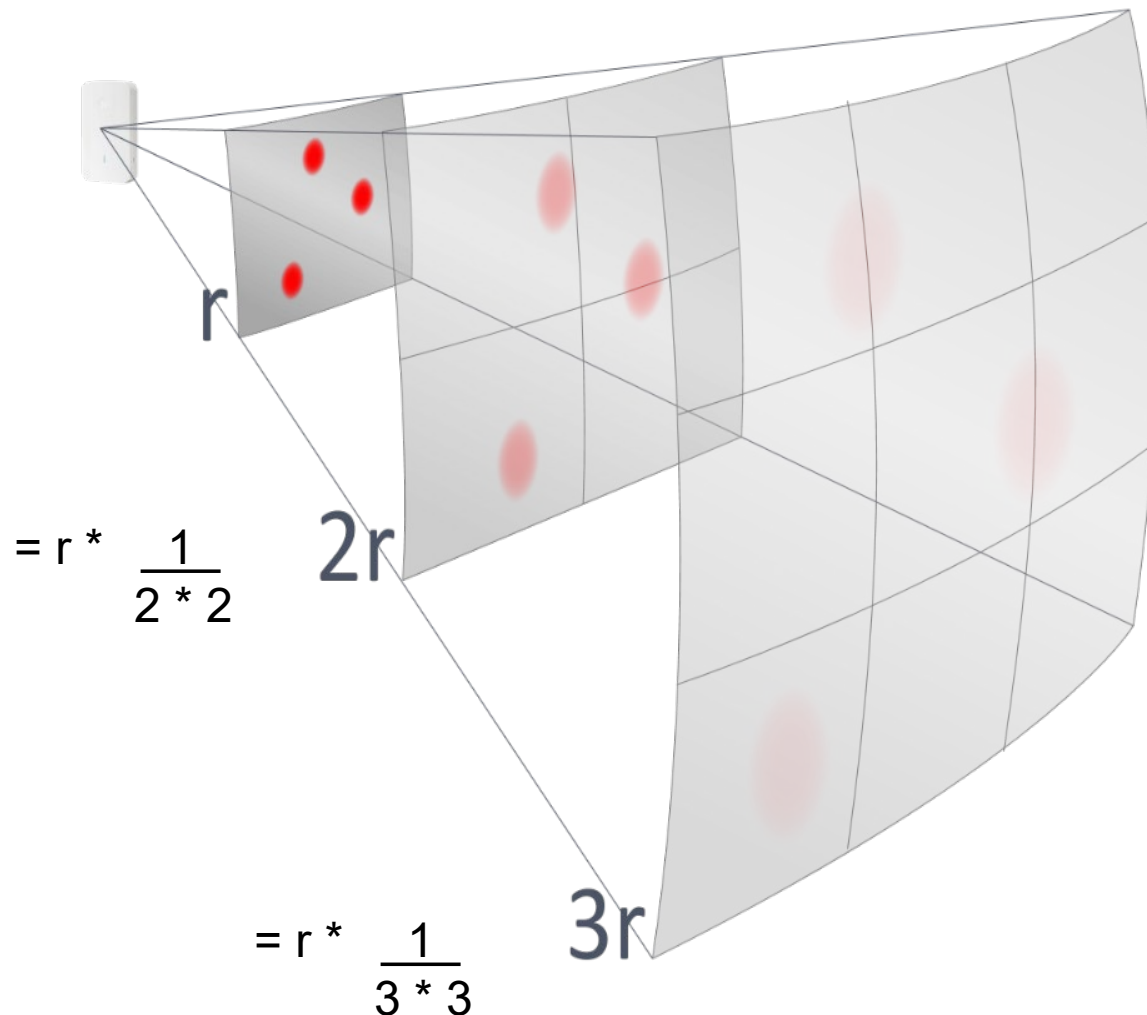
Inverse Square Law

signal level will be reduced by a factor that is inversely proportional to the square of the distance from the source

What that means

*The signal measured at distance **2r** will be 1/4th the signal at **r**, and the signal measured at **3r** will be 1/9th the signal at **r***
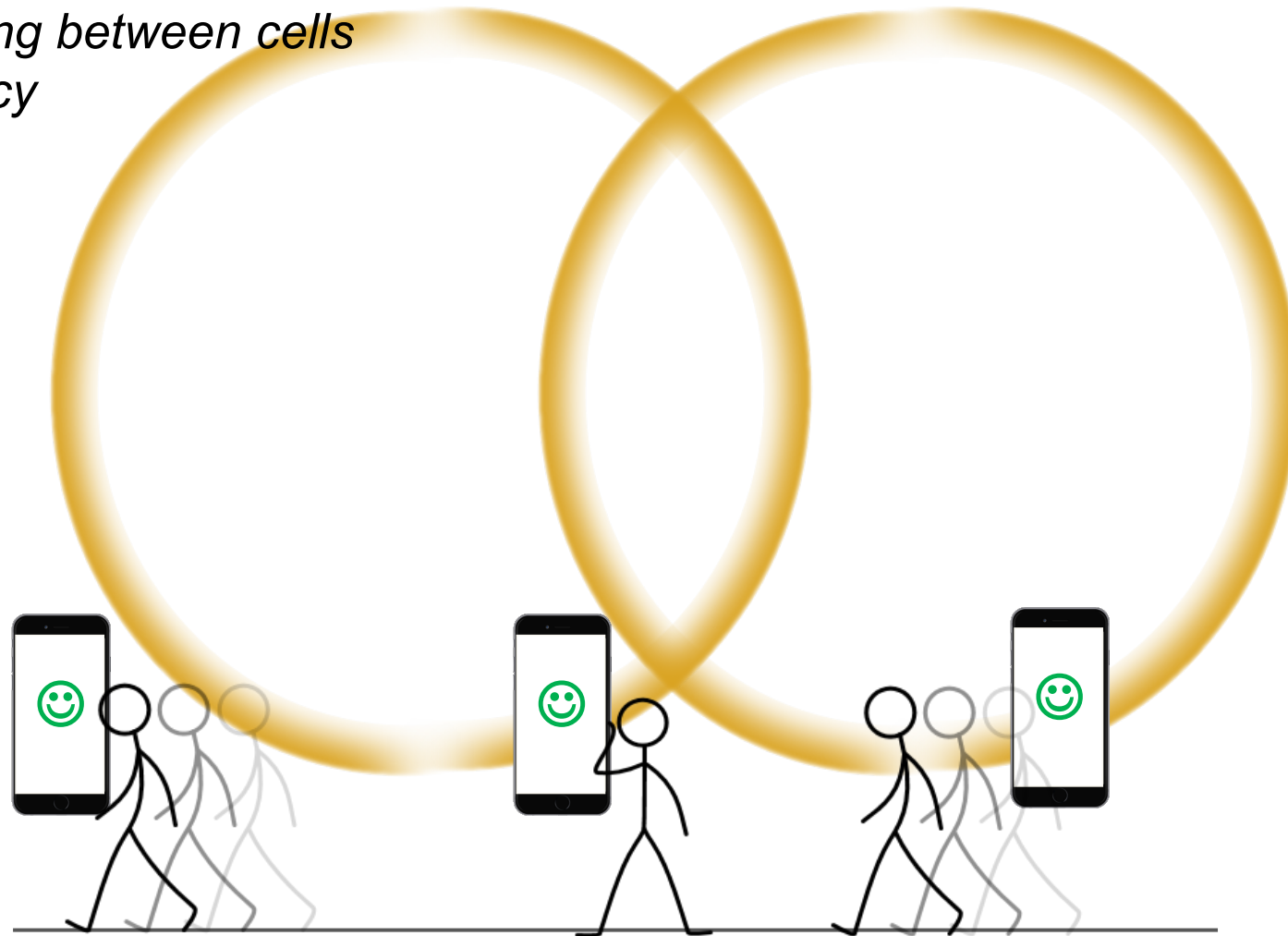
$$= r * \frac{1}{2 * 2}$$

$$= r * \frac{1}{3 * 3}$$

r

2r

3r

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Connection imbalance between wireless cells

- *Dropped connections*
- *Excessive client roaming scans*
- *High battery drain*

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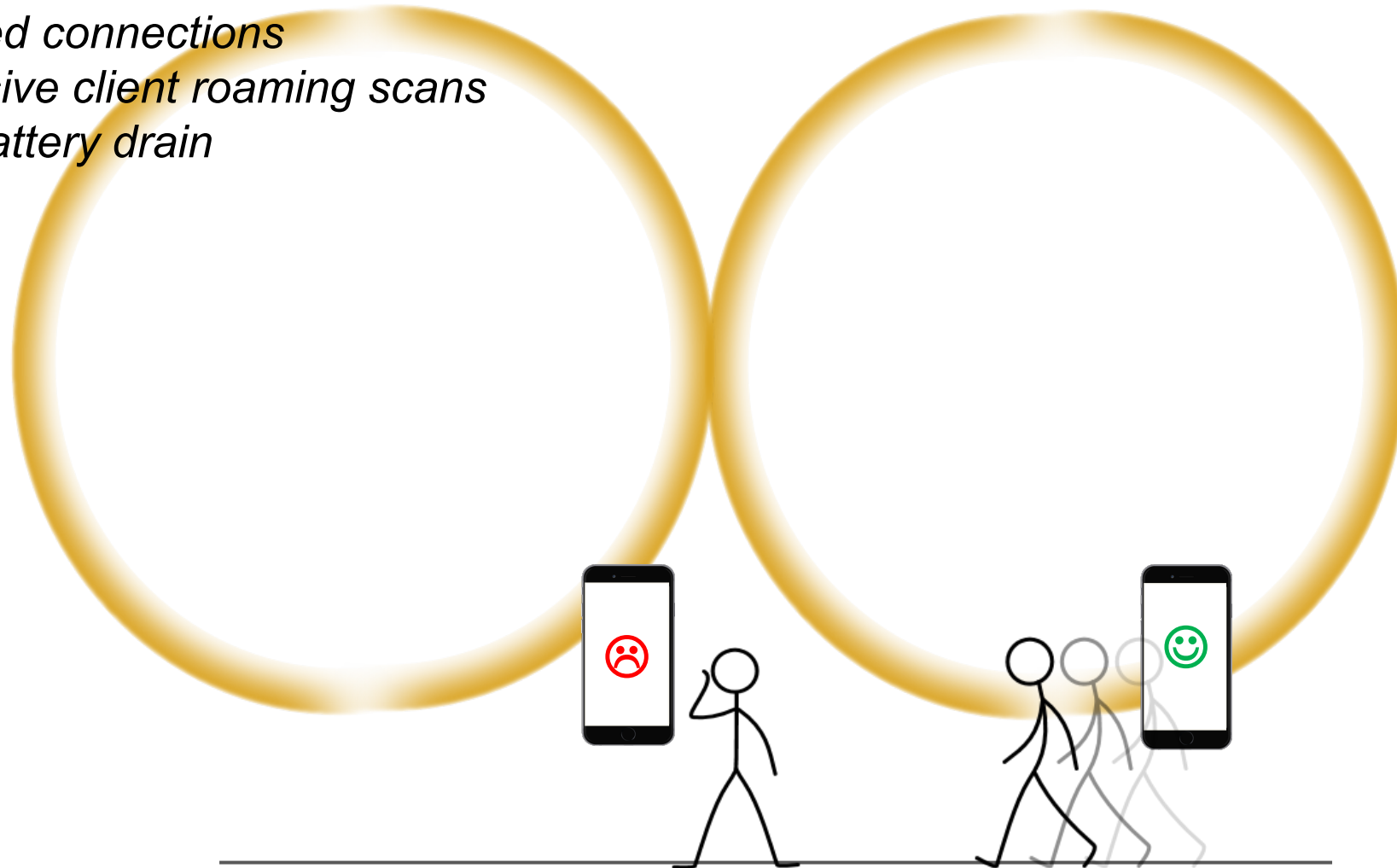
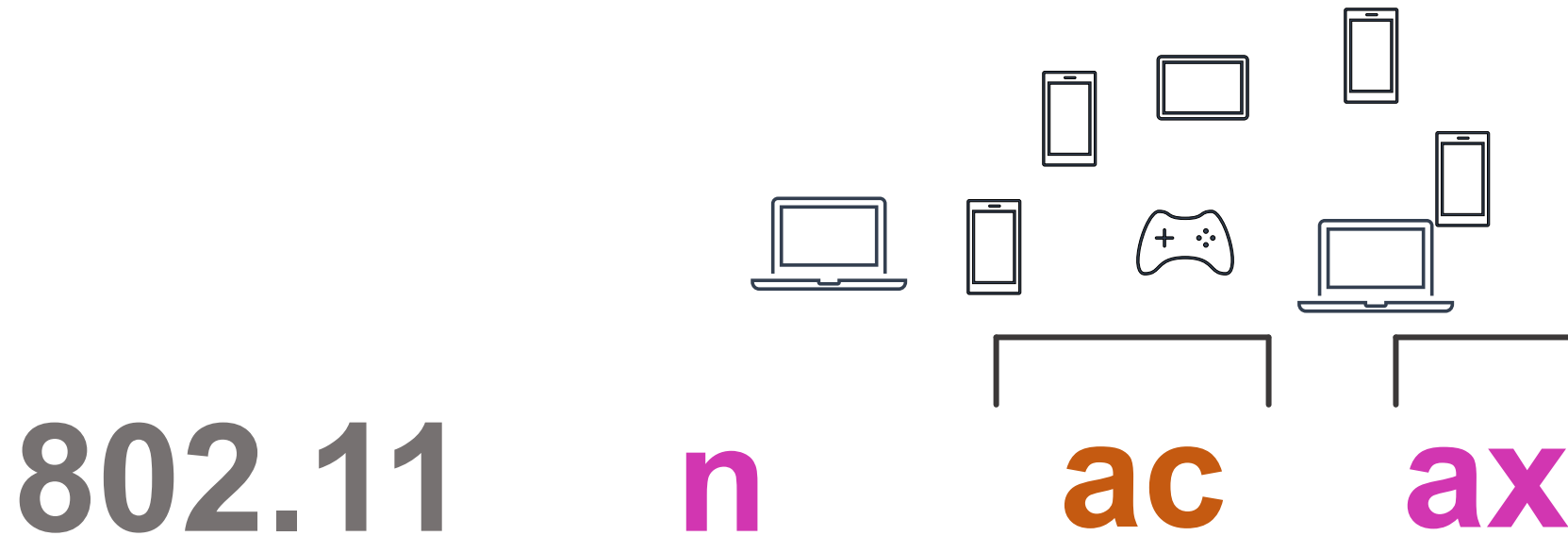## *Balanced datarates, 30% overlap between cells*

- *Consistent roaming between cells*
- *Low packet latency*
- *Good experience*

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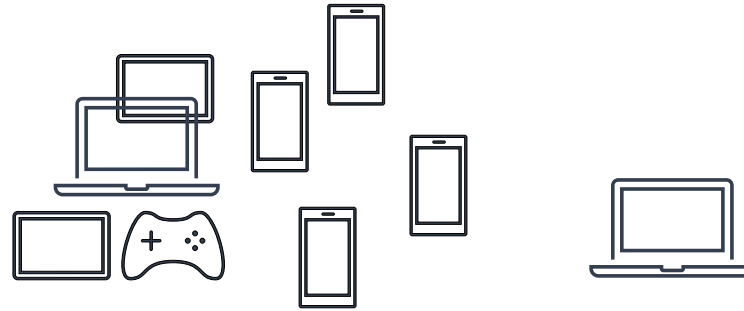
802.11 b g n a ac ax

Designed for coverage

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802.11 **n** **ac** **ax**

2.4GHz best for IOT devices, and coverage holes

Designed for capacity

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- **Two frequency bands used in 802.11 Wi-Fi: 2.4GHz and 5GHz (for now)**

- **2.4GHz has 3 non-overlapping channels: 1, 6, 11**

  - Difficult to separate in dense environments

  - Shared with RF interfering sources e.g. cordless phone, Bluetooth, mifi devices, microwave

- **5GHz has 24 non-overlapping channels**
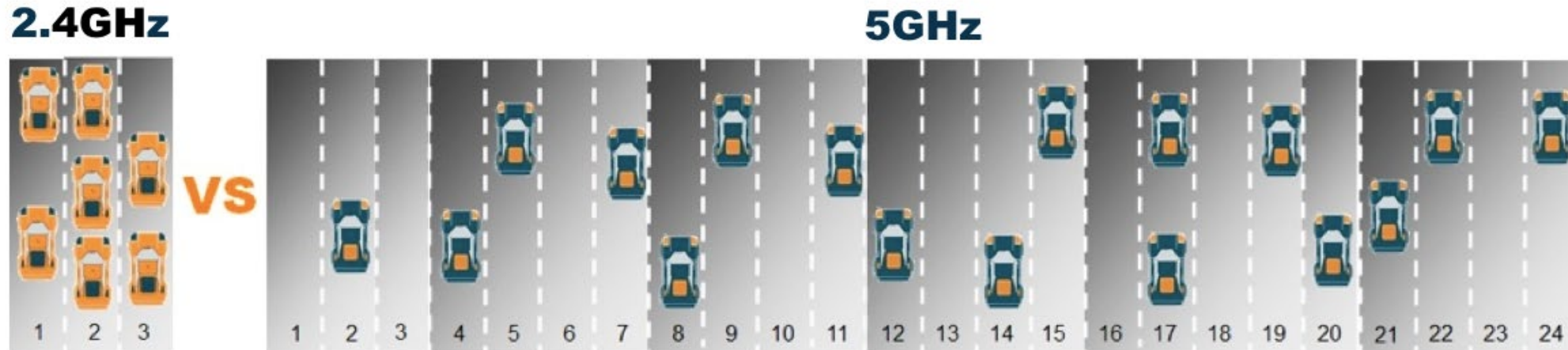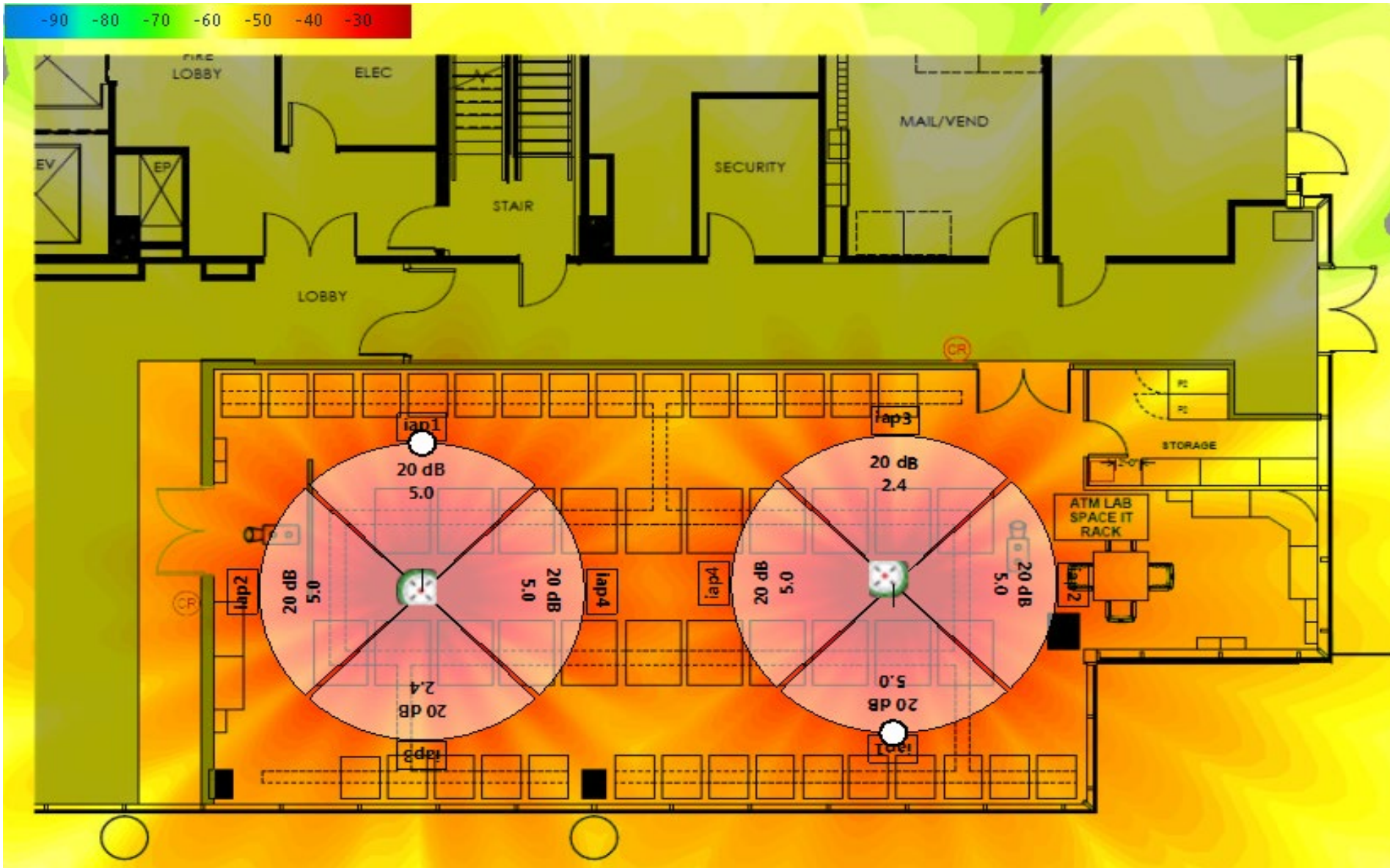
Software Defined Radios with XV3-8 - Wifi 6
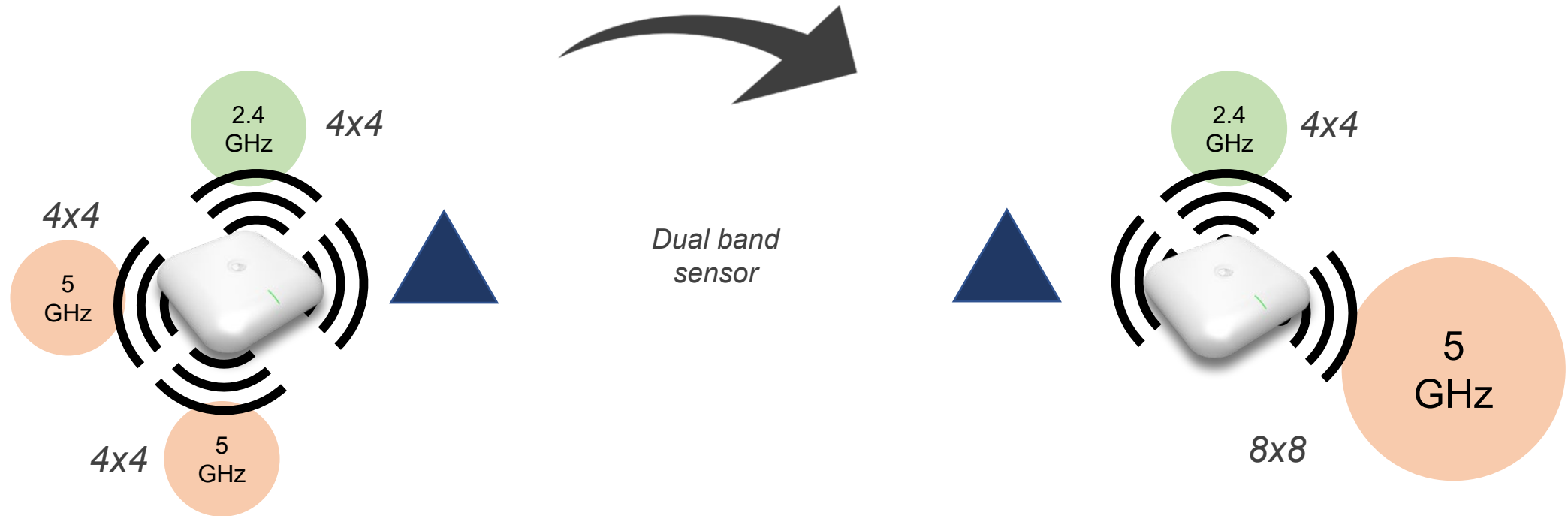
Legacy Networks: Double 5GHz capacity for Education, Hospitality, Enterprise

Ideal for 11n, 11ac mixed with new 11ax devices

**802.11ax: Migrate to 8x8 for full MU-OFDMA, MU-MIMO, IOT ready**

Ideal for 11ac, mostly 11ax, IOT mixed networks

Using SDR to enable flexible deployments

- 2 AP's Providing 6 total 5ghz radios and 2 in 2.4ghz

- Maximize Spectrum without turning off radios

- Lowest Total Cost of Ownership due to less AP's, Cabling and Switch Port Costs

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Using SDR to enable flexible deployments
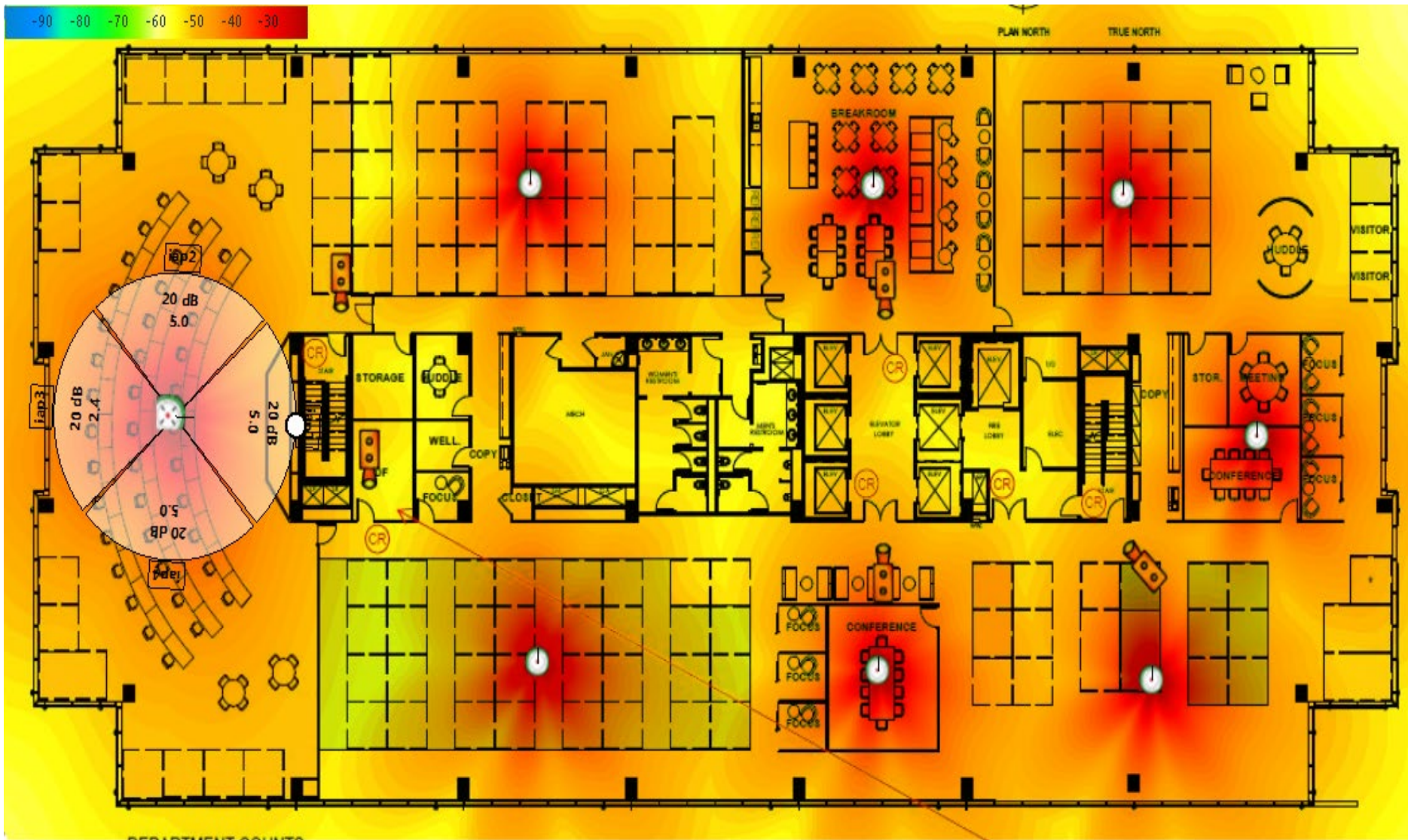
- Right Size the design based on number of users and Application Importance

- No turning off fixed 2.4ghz radios

- Dedicate radios for your faster clients

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SDR live demo

Note

- Easily test with and without SDR

- No special firmware to load, it's built in and ready

- Allows flexible deployments tailored to the client types, applications

Summary of the network planning and configuration

Task	Bitrate	Notes
RF Planning	**-60dBm** RSSI, **30dB** SNR	Higher SNR = higher rate, lower latency, but requires more careful AP installation and configuration to control CCI/ACI
Configuration	**Disable** 802.11abg	These protocols party like it's 1999… time to say goodbye
	Prune rates <24Mbps	Reduces the range of the wireless cell advertisements, reduces connections to far away clients
	Enable **802.11kvr**	Smart protocols that enable better resource management, roaming for improved client experience
	Enable **Automatic RF management**	Wireless vendor specific optimizations to mitigate interference, assist with roaming, and select optimal power and channel

Thank you