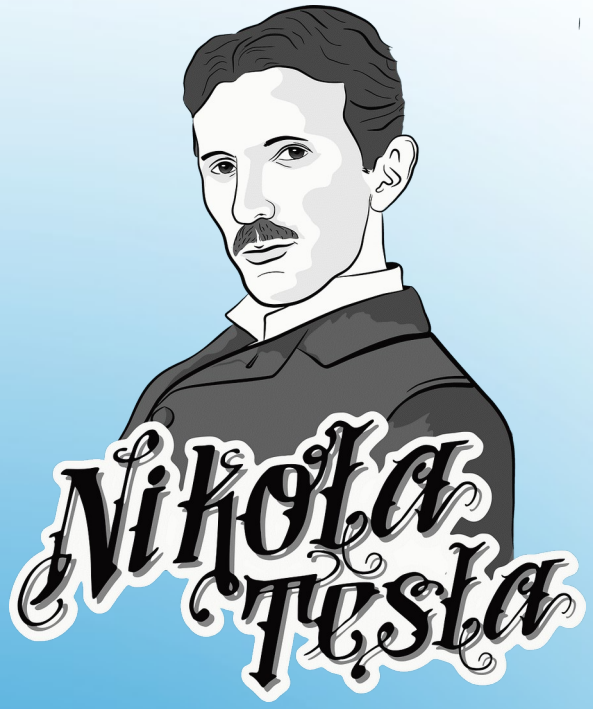
Lorin B Olsen
Chief Technologist, MIS Networks, Inc.
Principal Consultant, Lobostrategies.com

Wireless Infidelity



“When wireless is perfectly applied, the whole earth will be converted into a huge brain**...**”
- Nikola Tesla

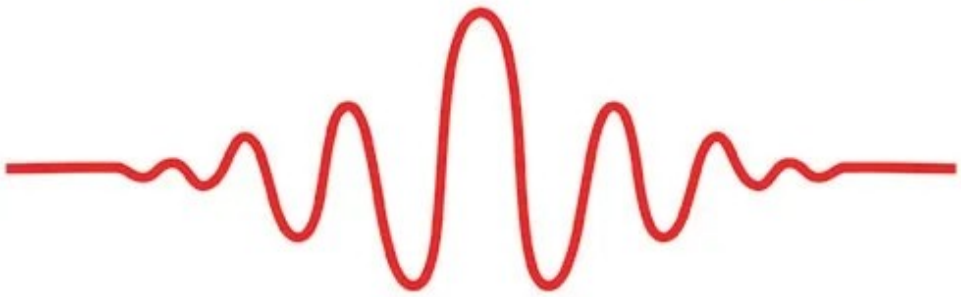
Lessons From History

- A Little Bit of (Meta)Physics
- A Little Bit of Federal Regulation
- A Little Bit of WiFi History
- A Little Bit of RF Engineering
- Personal Applications
- Future Solutions

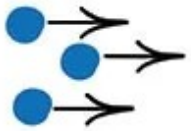
Agenda

Wave-Particle Duality

$c = 299\,792\,458$ m/s

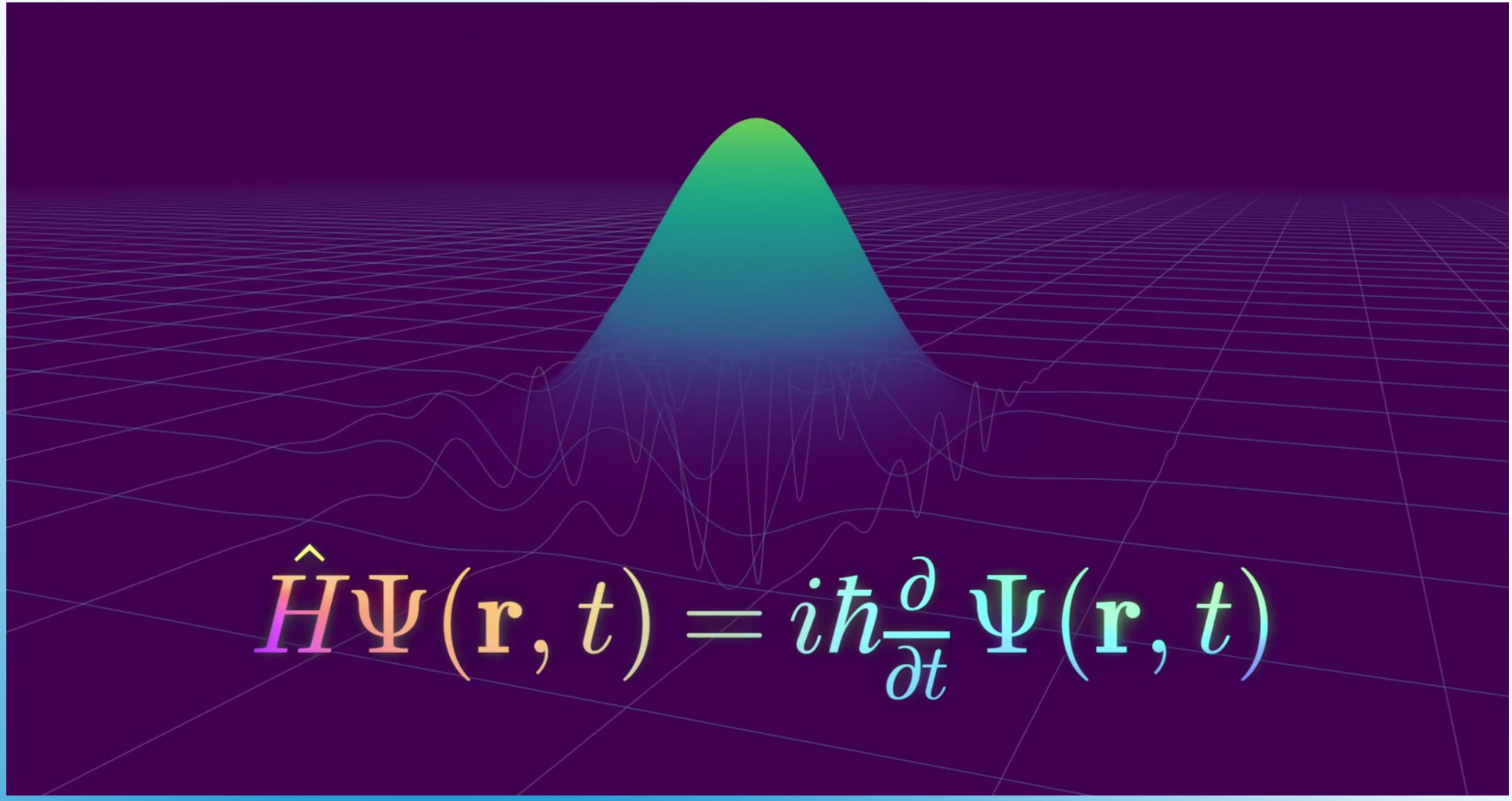


wave

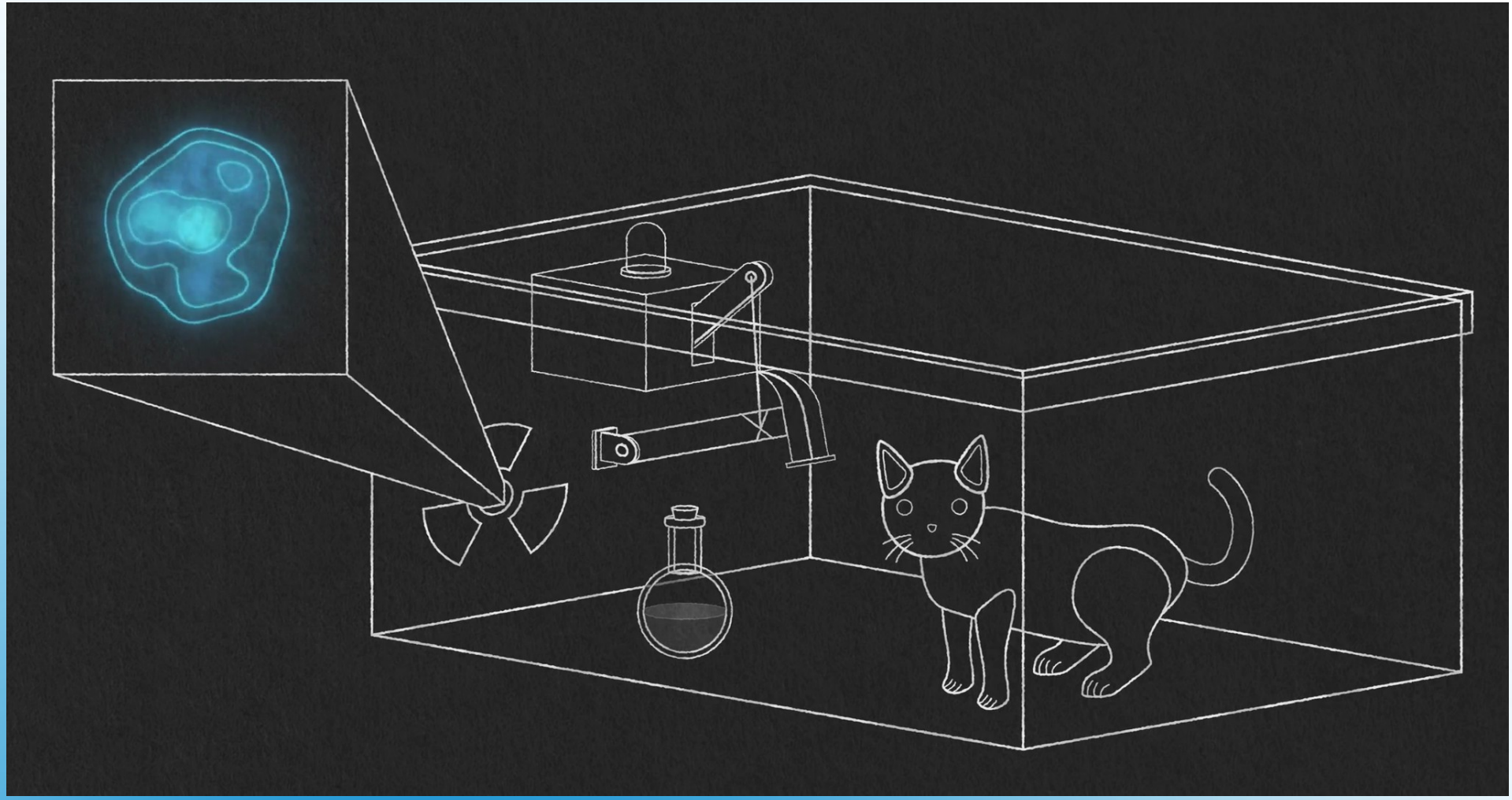


particle

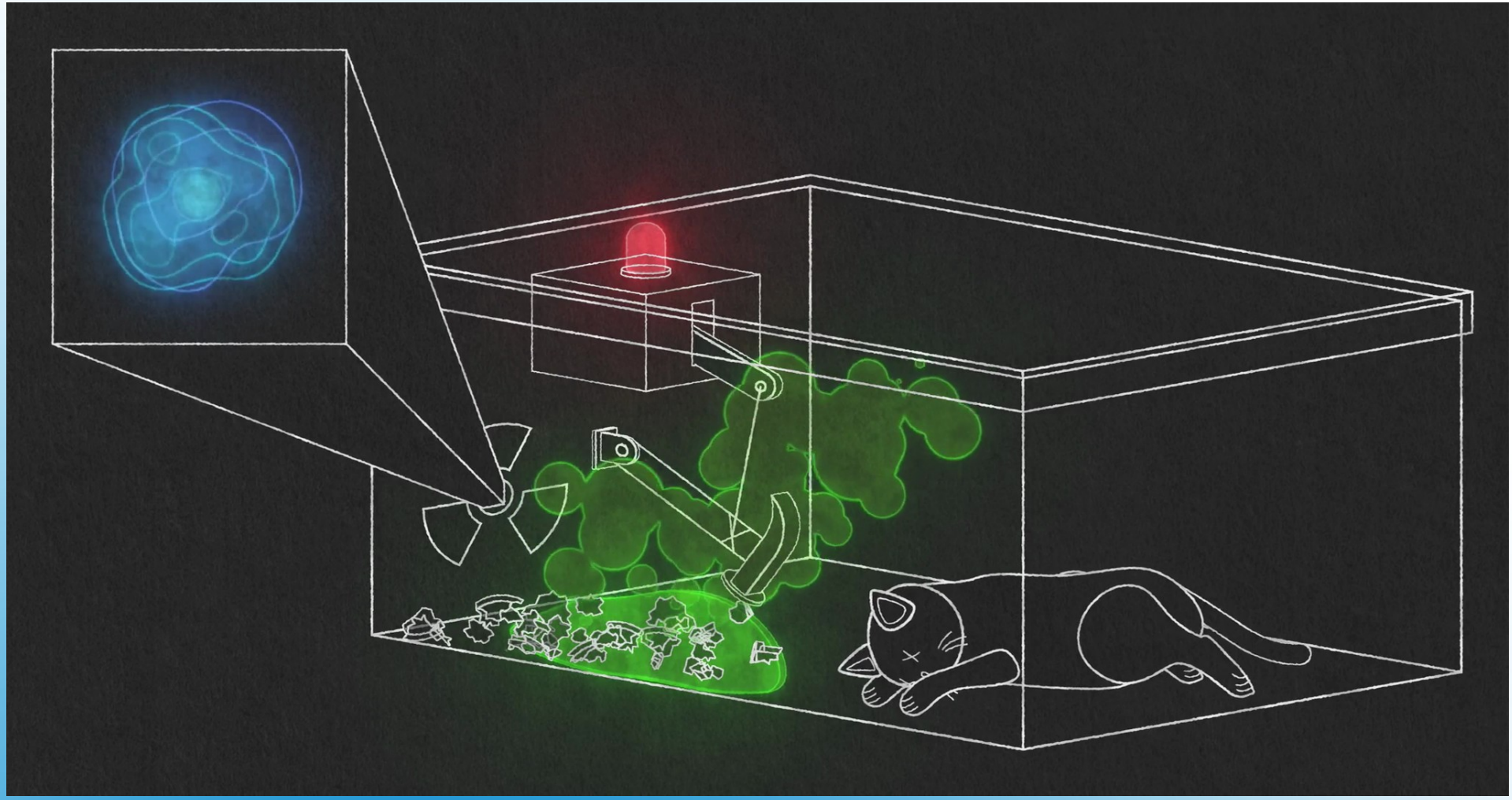
A Little Bit of Physics



Schrödinger's Equation



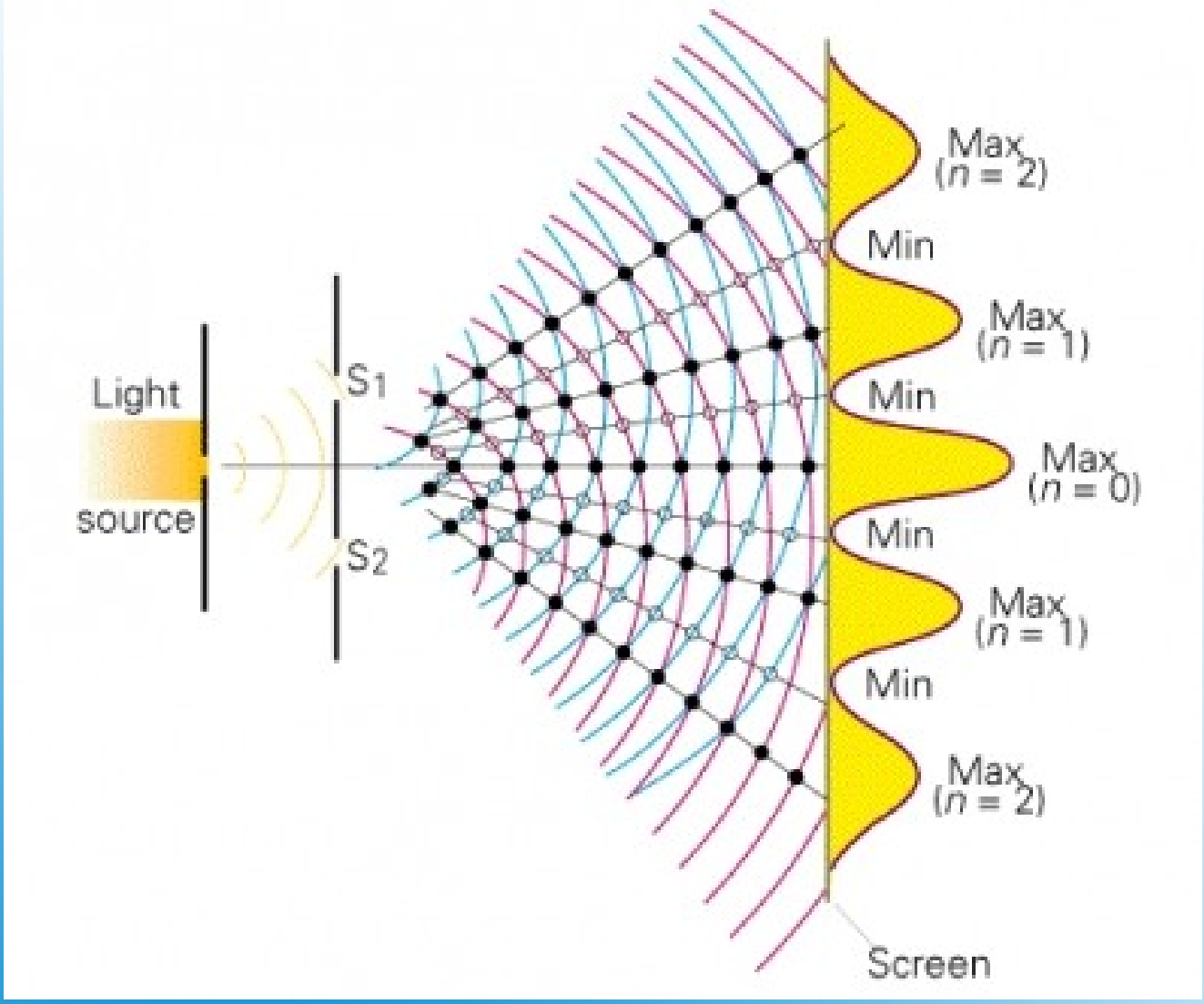
Living?



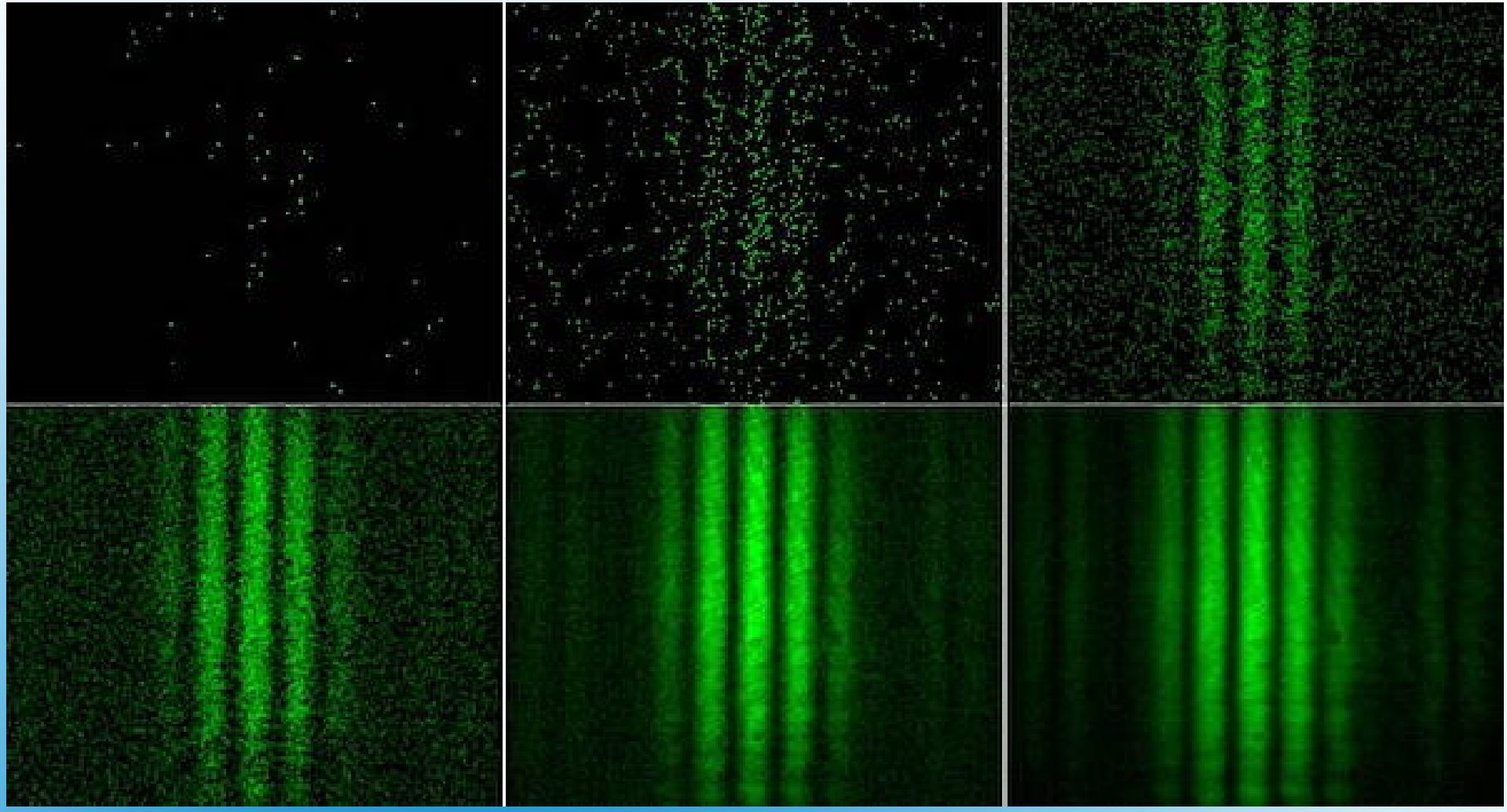
Or Dead?

"This interpretation (that quantum mechanics is a complete description of reality) is, however, refuted, most elegantly by your system of radioactive atom + Geiger counter + amplifier + charge of gun powder + cat in a box, in which a psi-function of the system contains the cat both alive and blown to bits. Is the state of the cat to be created only when a physicist investigates the situation at some definite time? Nobody really doubts that the presence of absence of the cat is something independent of the act of observation. But then the description by means of the psi-function is certainly incomplete…"

From One Physicist to Another

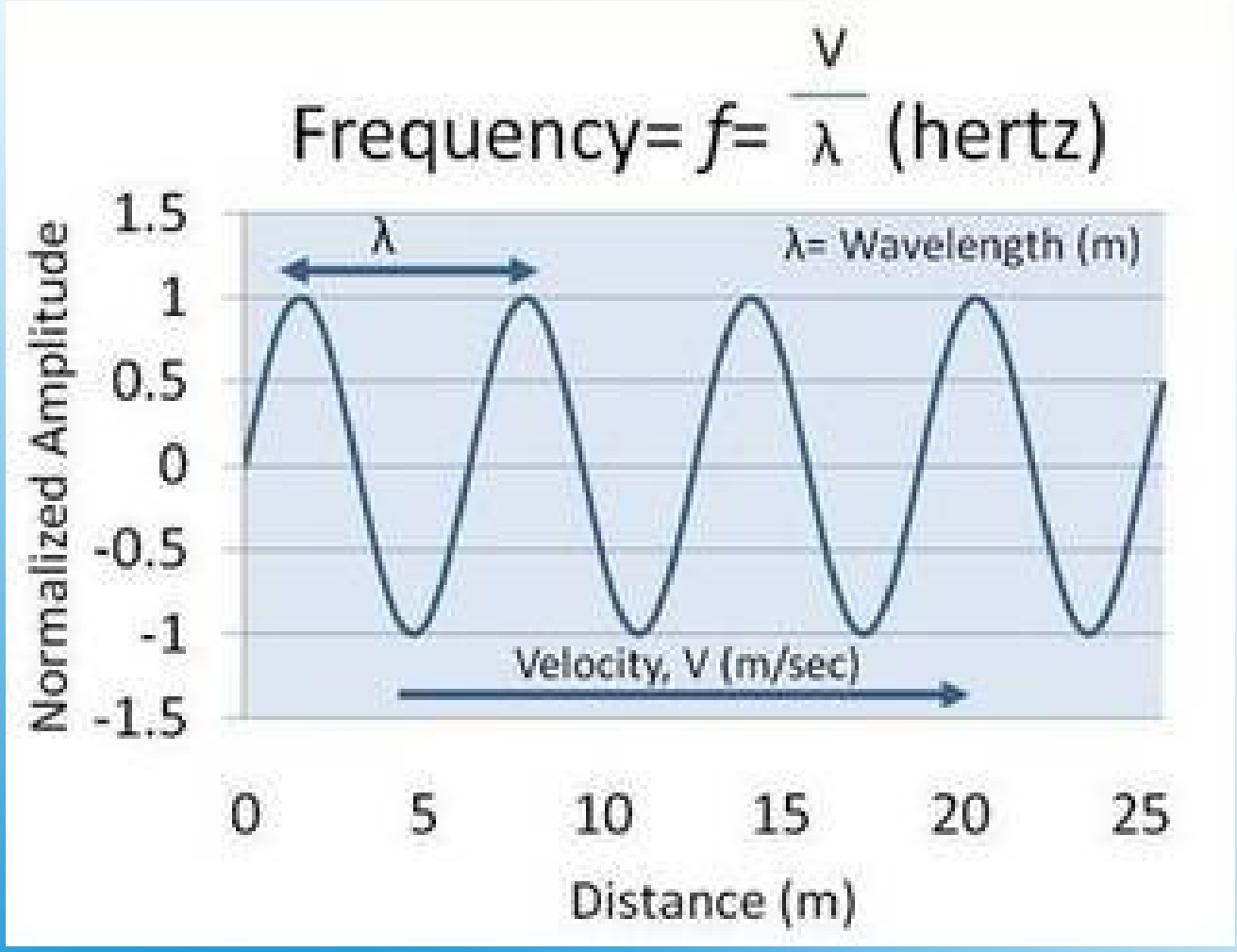


Double Slit Experiment

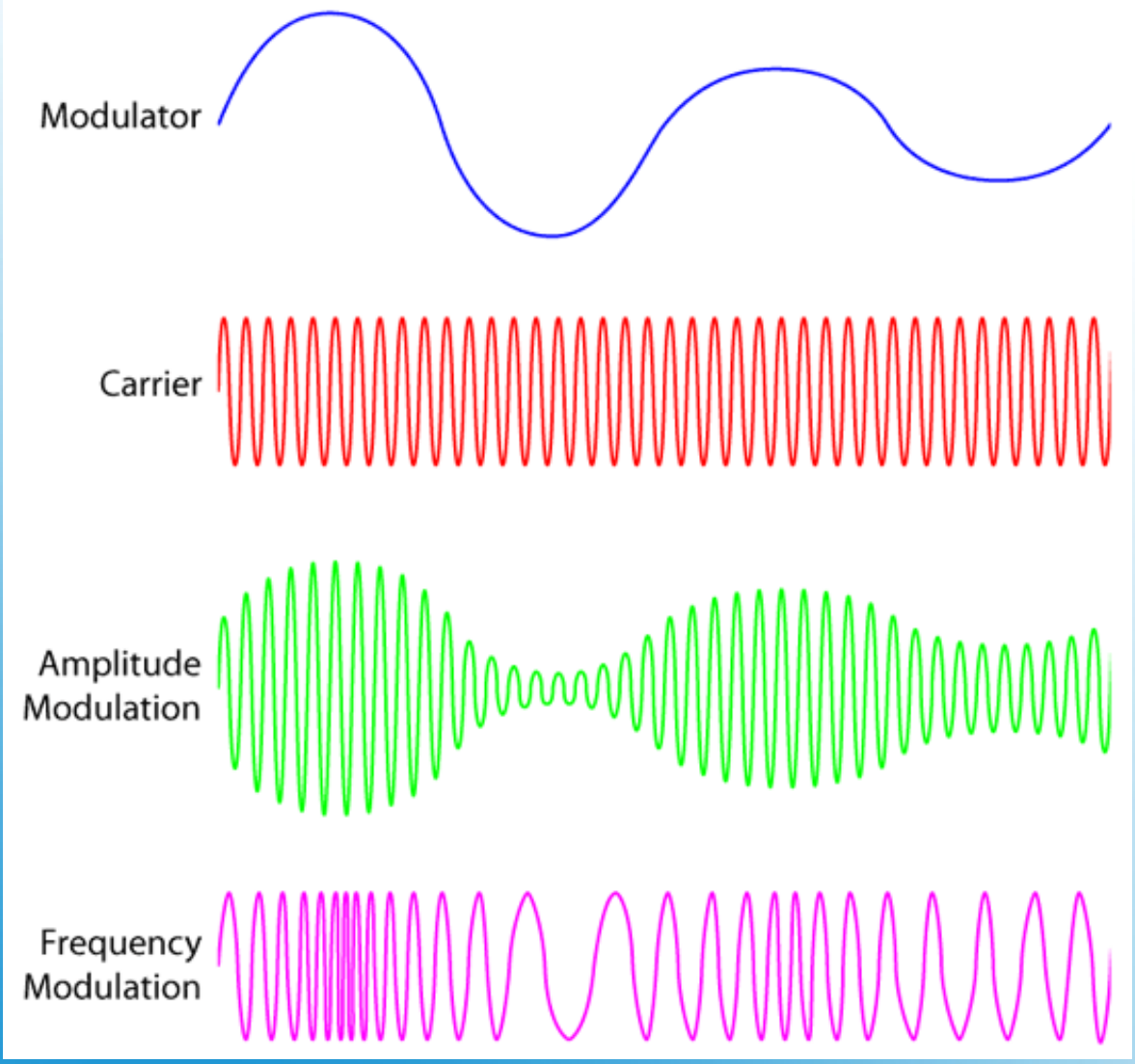


Double Slit Experiment

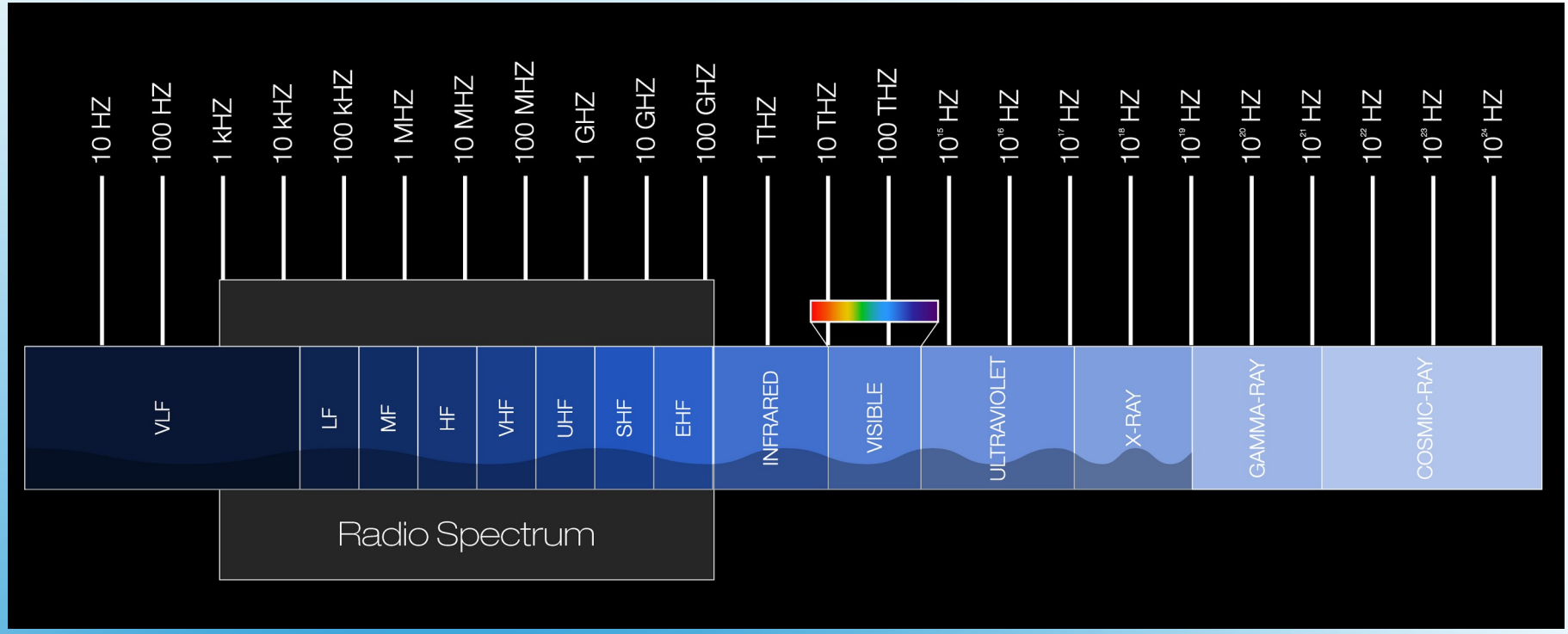
No Hollyweird Allowed



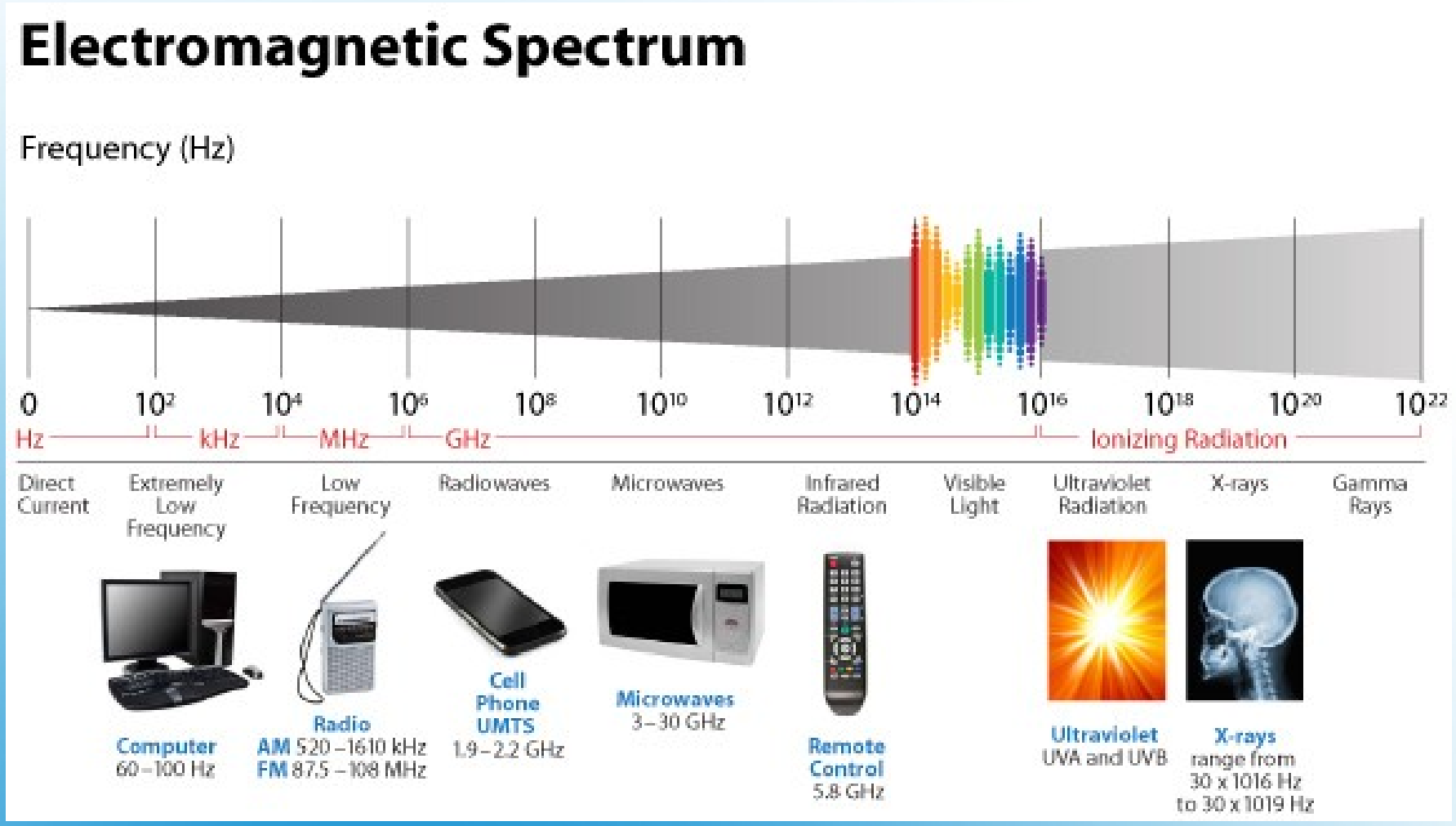
Just the Basics



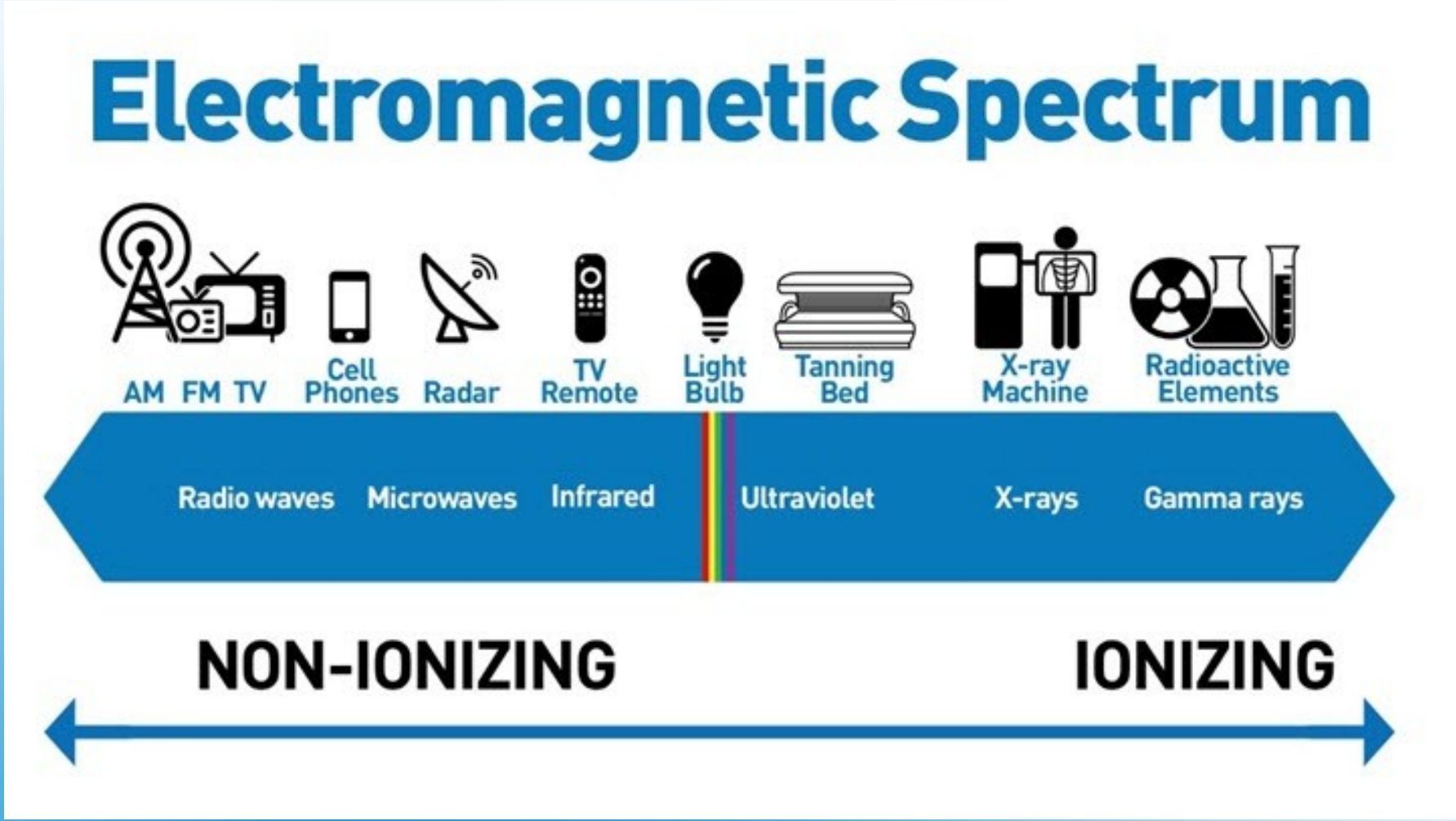
A Little Bit of RF Engineering



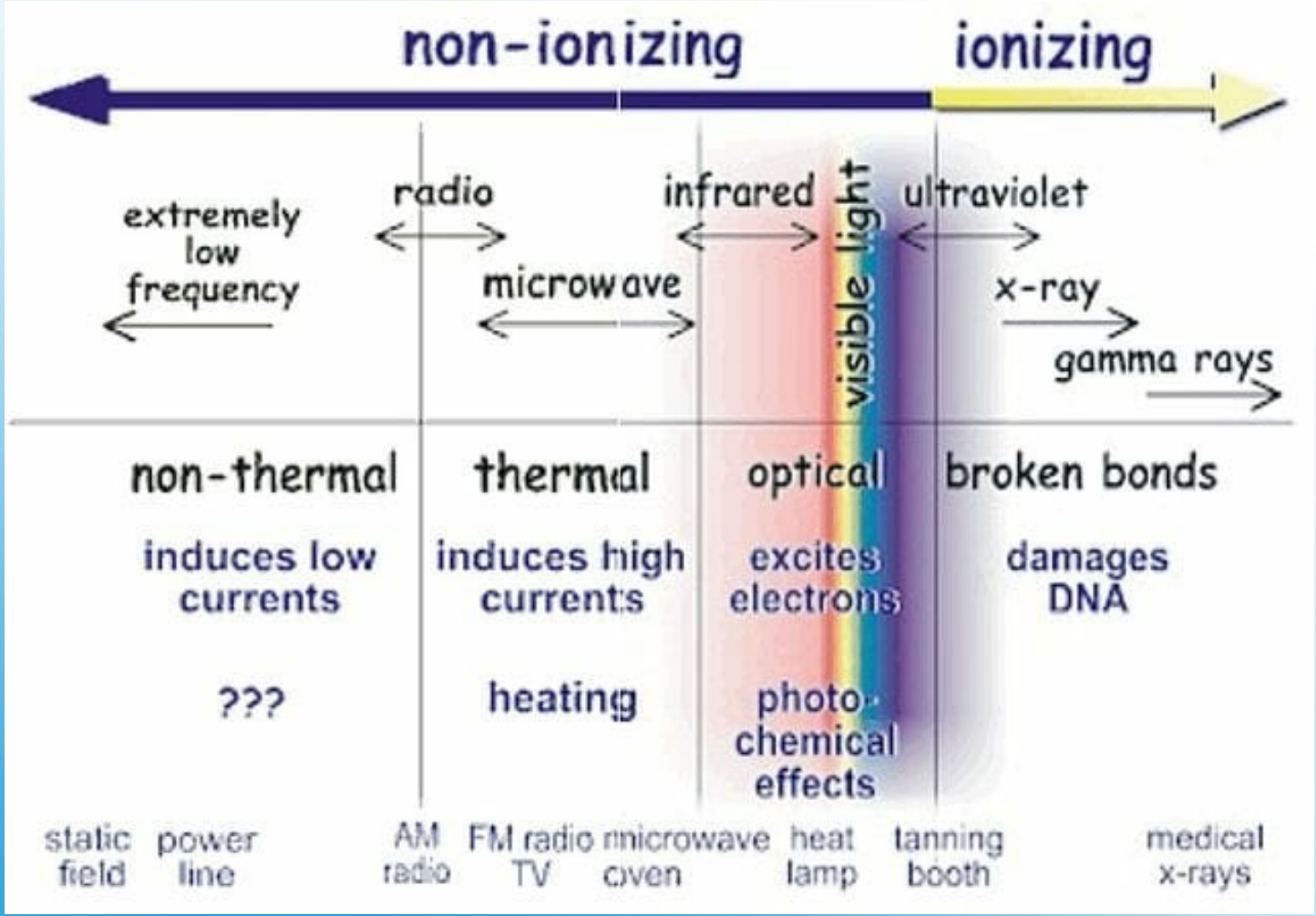
The Electromagnetic Spectrum



Use of the Spectrum



The Effects of the Spectrum



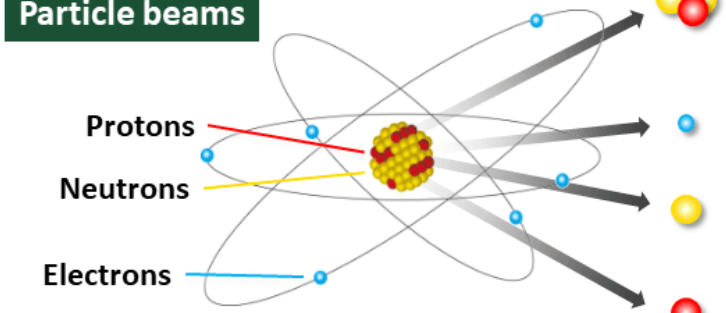
The Effects of the Spectrum

Radiation

Types of Ionizing Radiation

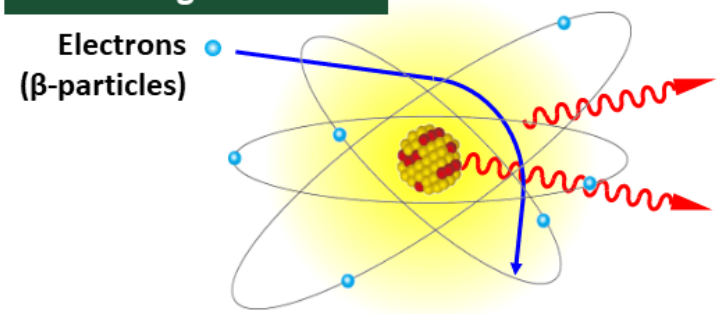
Ionizing radiation — Radiation that causes ionization

Particle beams



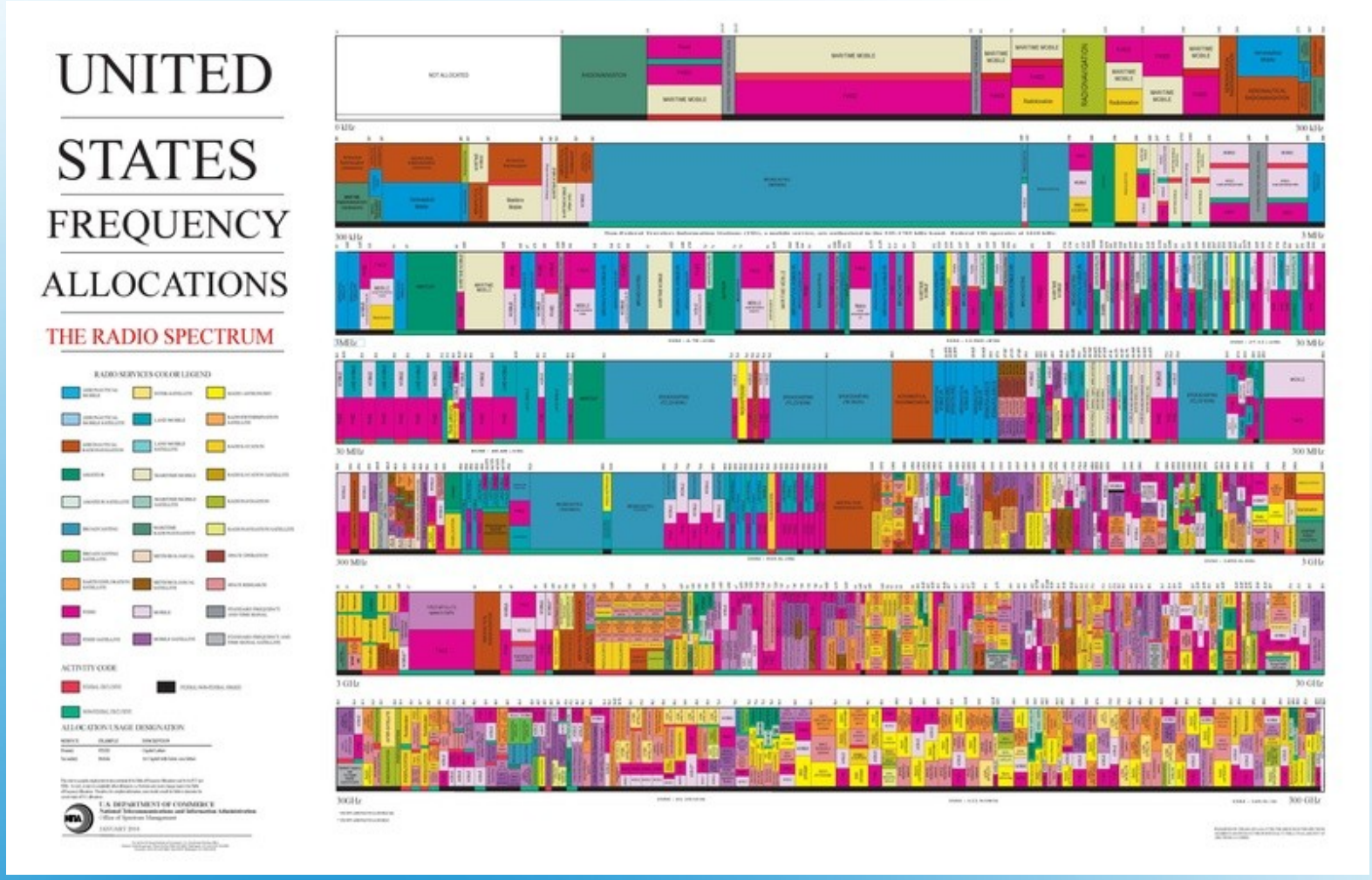
- α-particles (helium nuclei ejected from a nucleus)
- β-particles (electrons ejected from a nucleus)
- Neutron beams (produced in nuclear reactors, accelerators, etc.)
- Proton beams (produced in accelerators, etc.)

Electromagnetic waves

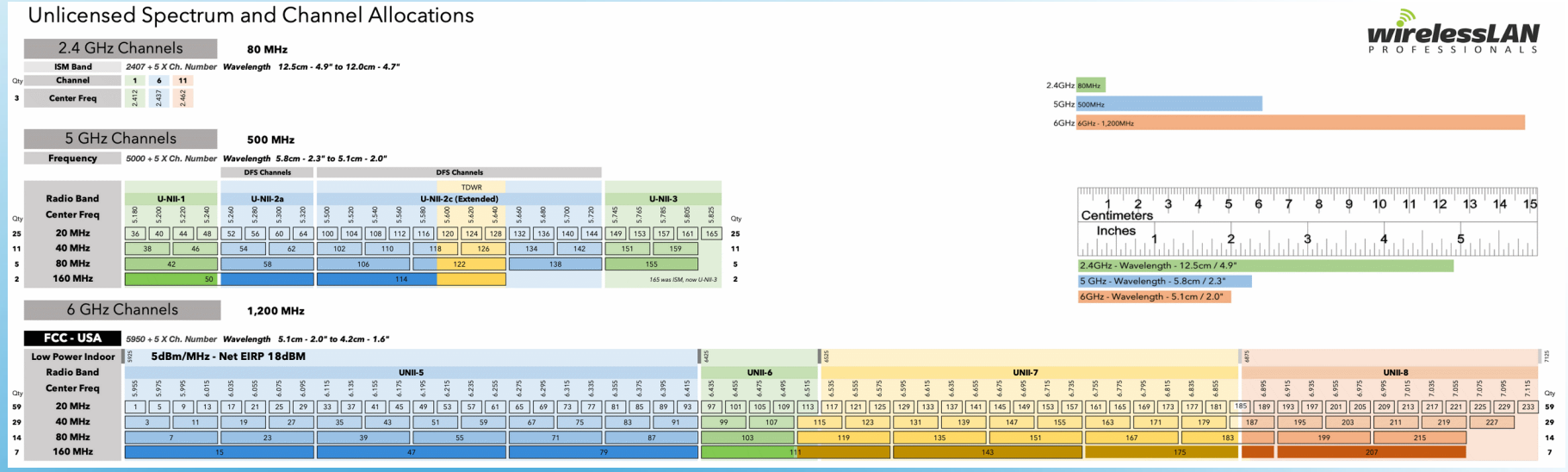


- X-rays (generated outside a nucleus)
  - * X-rays generated when electrons within an atom are caused to travel between orbits by incident electrons are called characteristic X-rays.
- γ-rays (emitted from a nucleus)

OK, Too Much Physics
How To Kill The Cat



A Little Bit of Federal Regulation



Federal Regulation of Unlicensed Spectrum

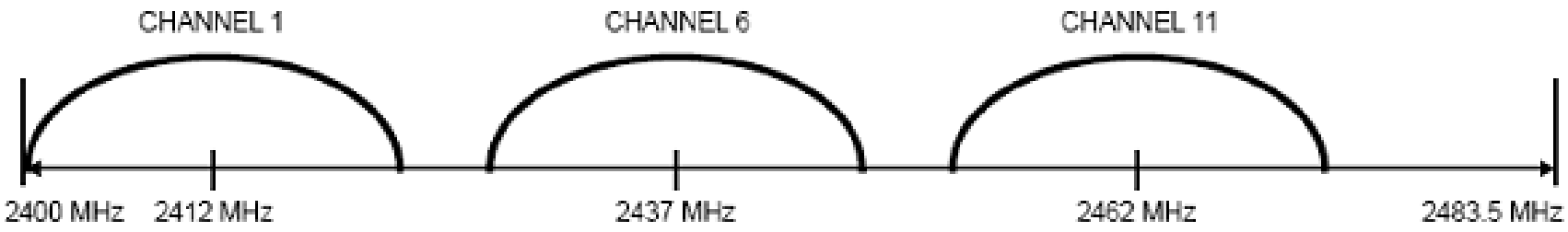


Figure 141—North American channel selection—non-overlapping

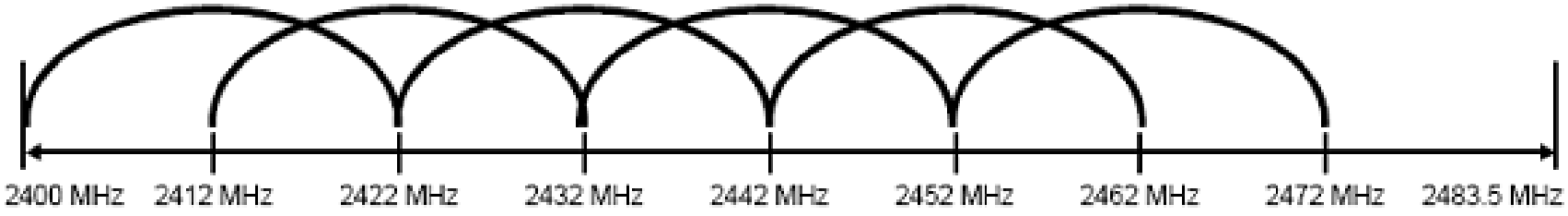
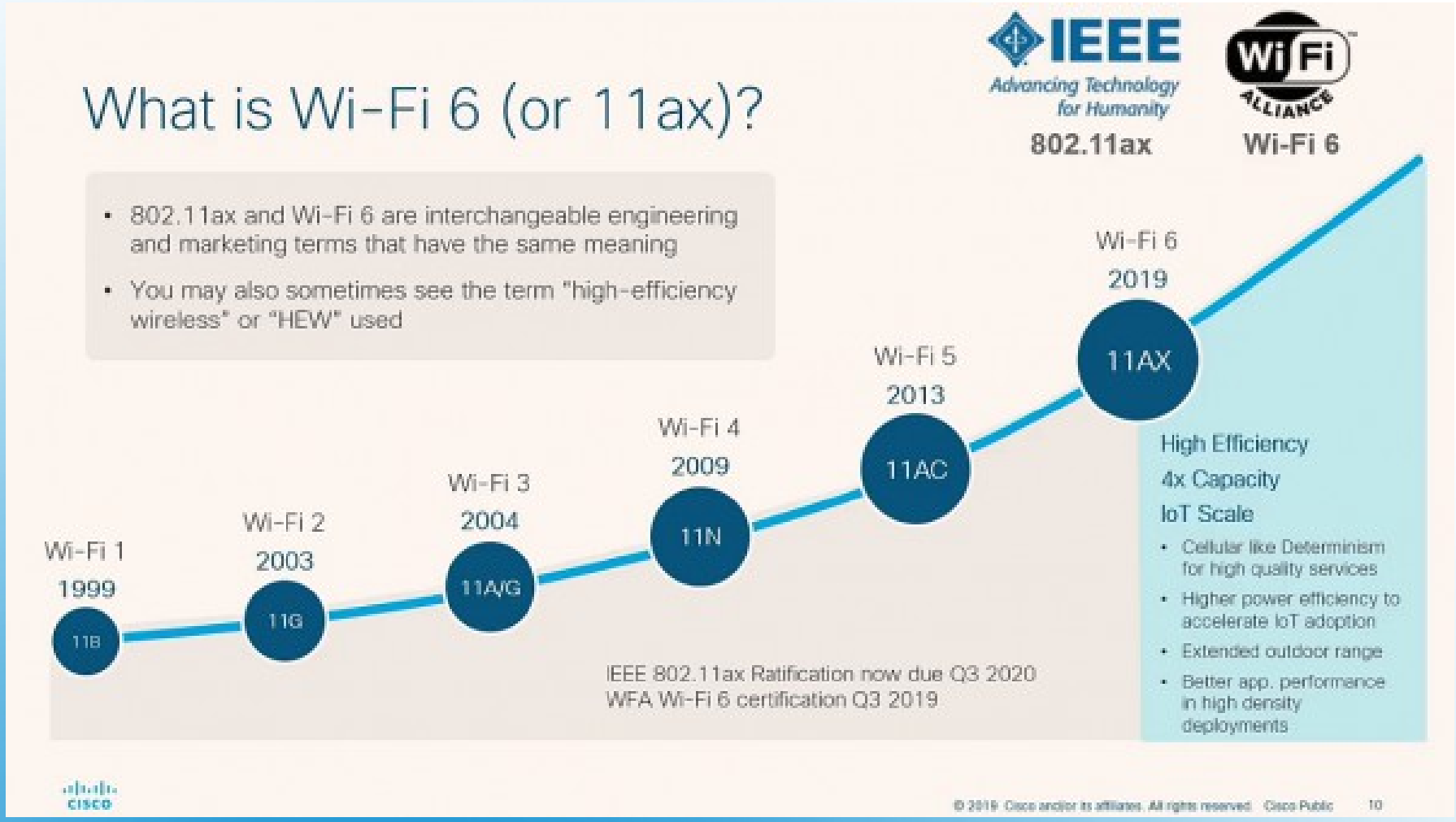


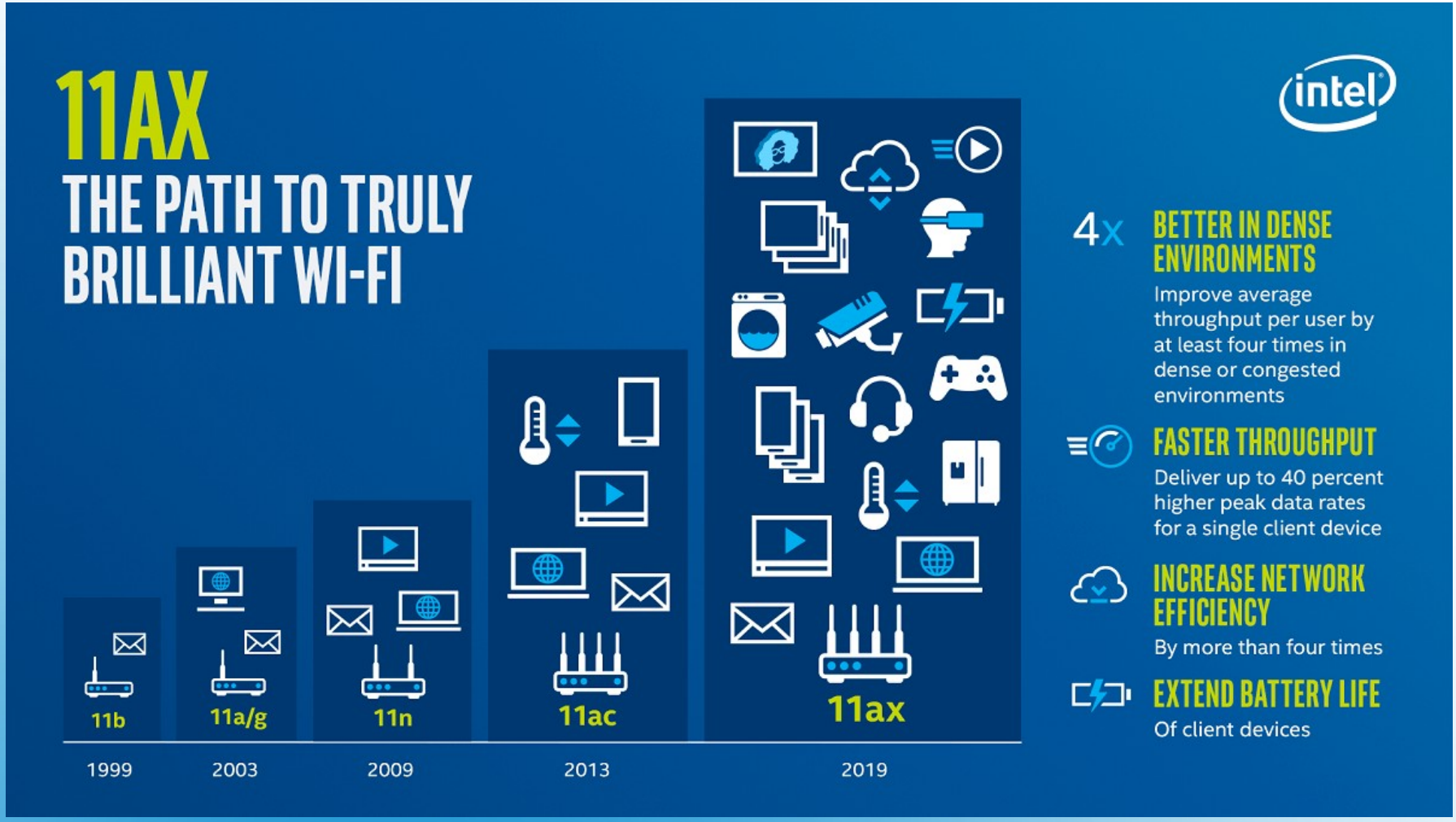
Figure 142—North American channel selection—overlapping

The Birth of WiFi

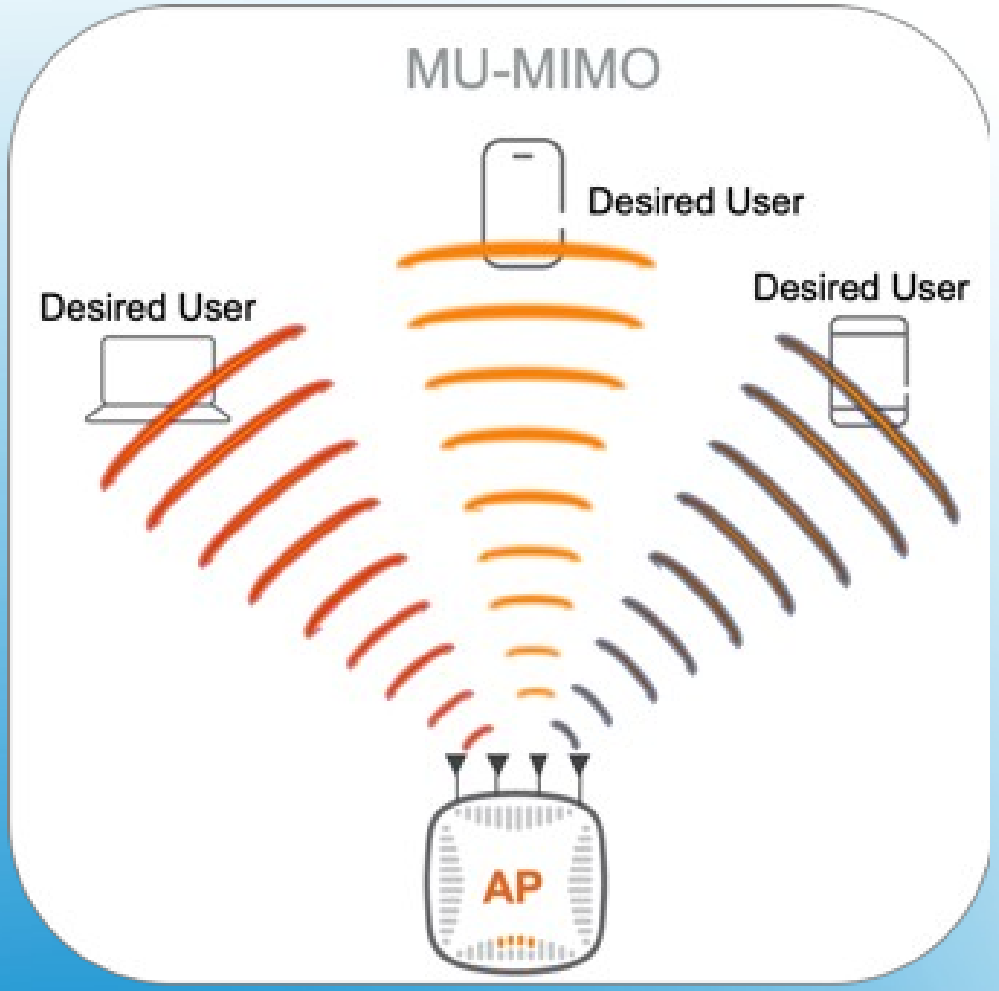
You Never Forget Your First...



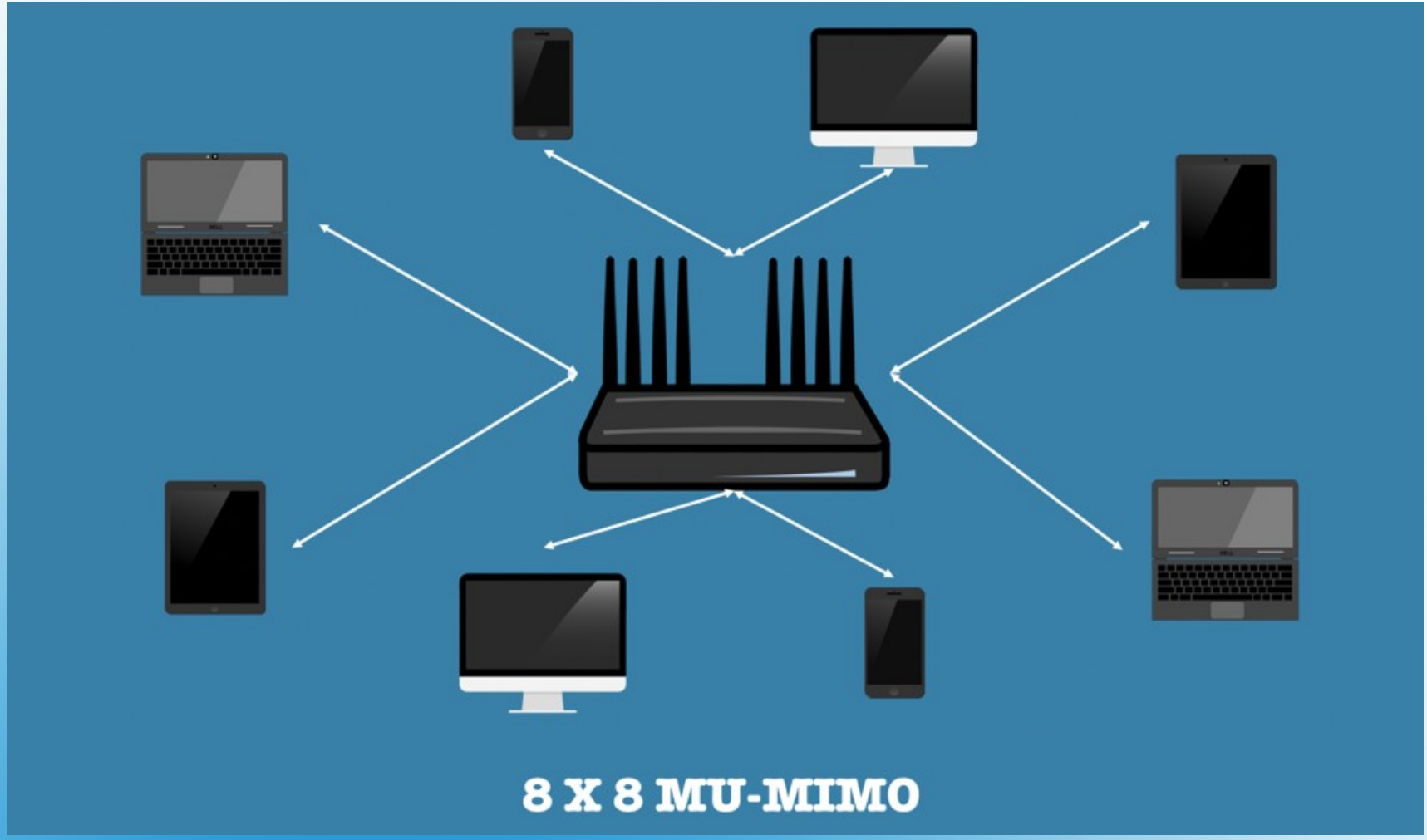
WiFi History



WiFi History



MU-MIMO Engineering



MU-MIMO Limitations

Categories of Enhancements

Spectral Efficiency & Area Throughput

1024 QAM
25% increase
in data rate

DL/UL MU-MIMO
w/ 8 clients

8x8 AP

2x increase
in throughput

Long OFDM Symbol

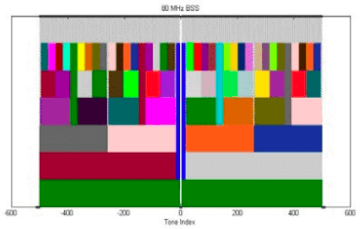
ac

ax

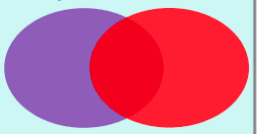
Up to 20%
increase
in data rate

High Density

OFDMA

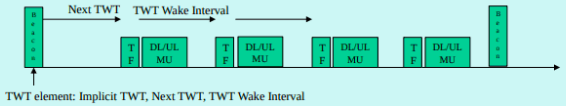


Spatial Reuse



Power Saving

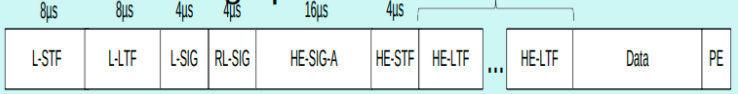
Scheduled sleep and wake times



20 MHz-only clients

Outdoor / Longer range

Extended range packet structure



Enhanced delay spread protection-long guard interval

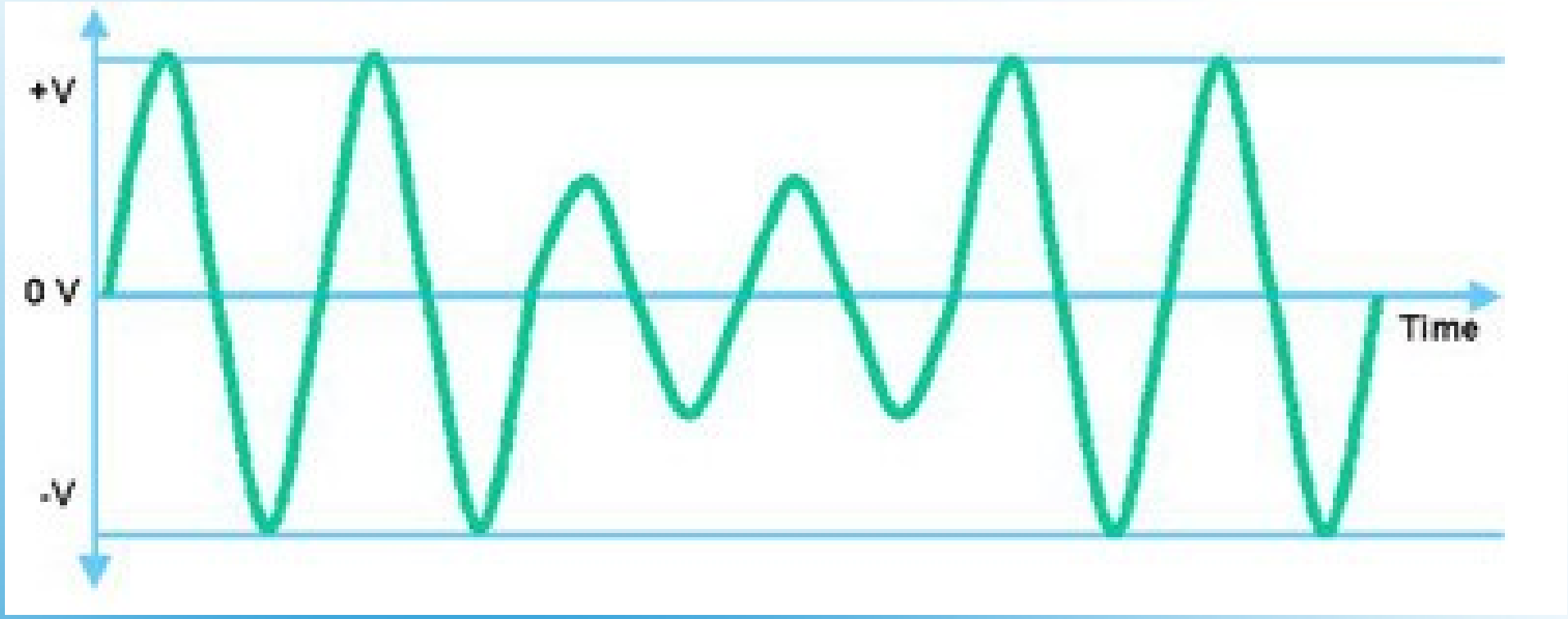
0.8us 11ac

1.6us 11ax

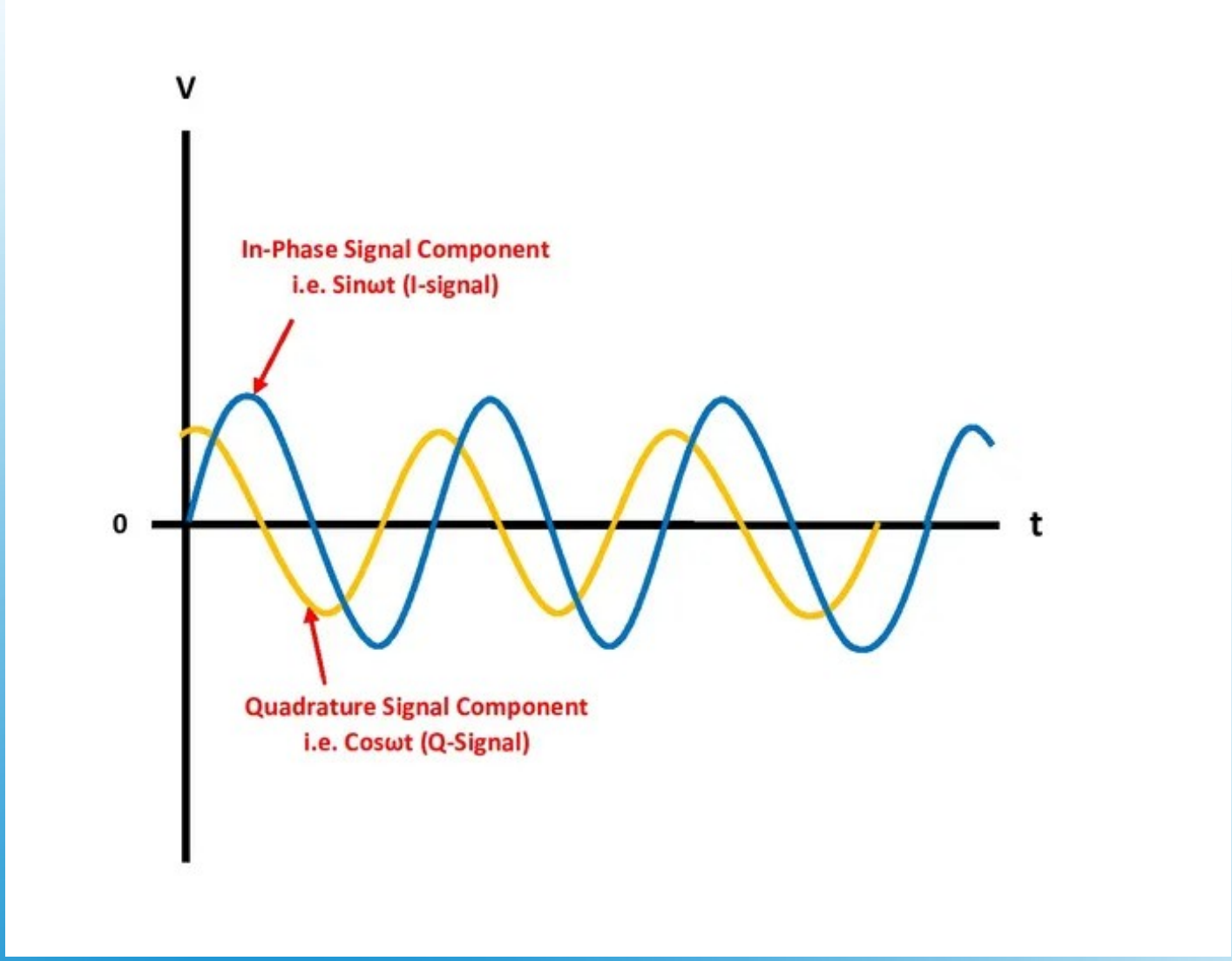
3.2us 11ax

aruba
a Hewlett Packard Enterprise company

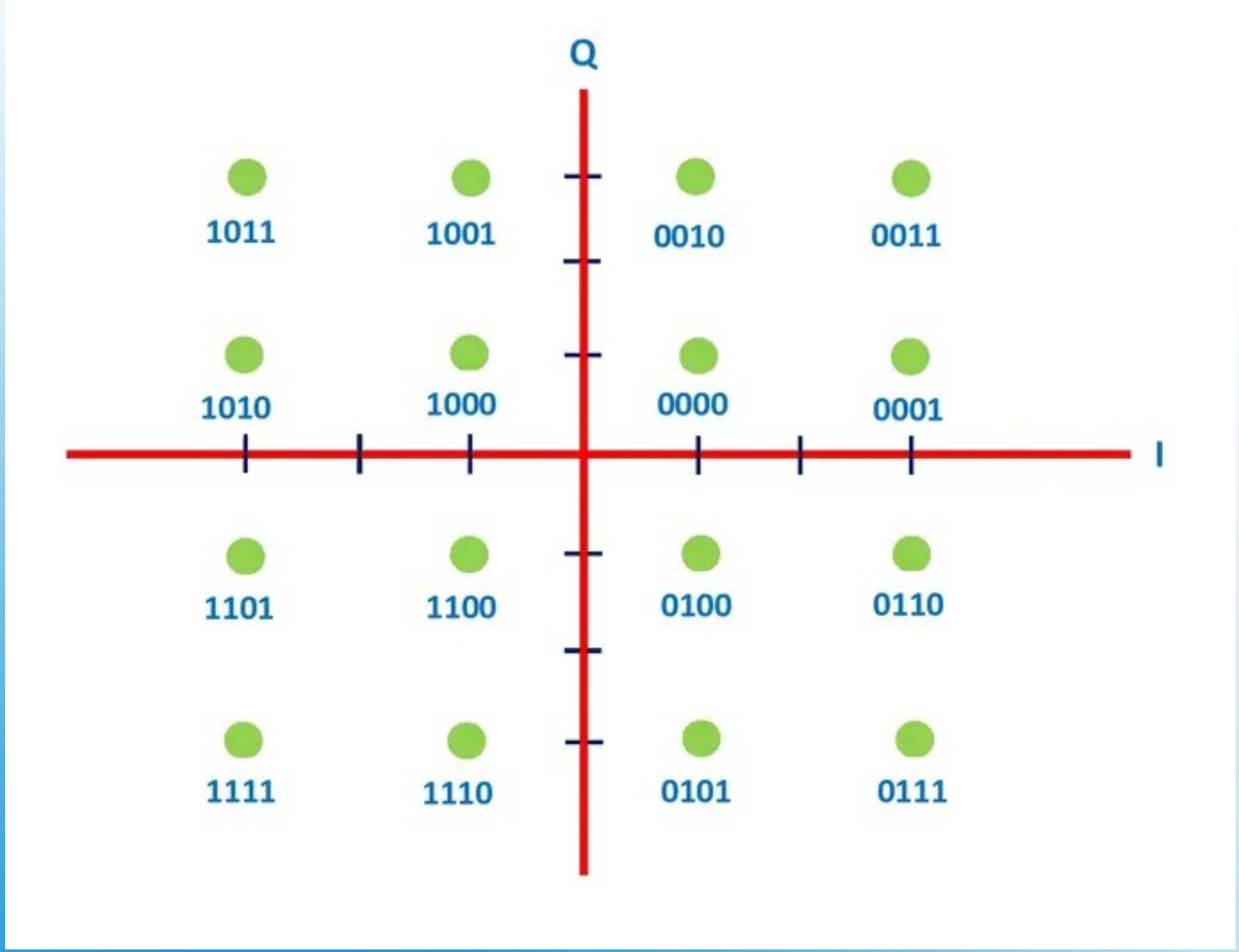
801.11ax Advantages



Amplitude Modulation

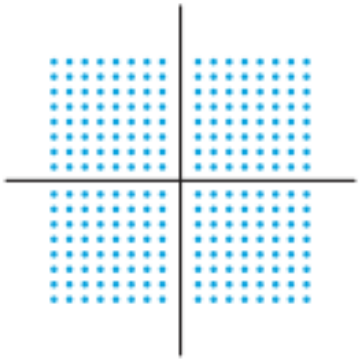
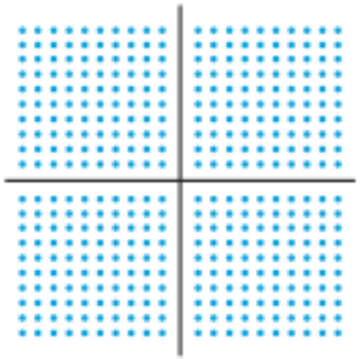


Quadrature Amplitude Modulation


Q
I
1011
1001
0010
0011
1010
1000
0000
0001
1101
1100
0100
0110
1111
1110
0101
0111

16QAM

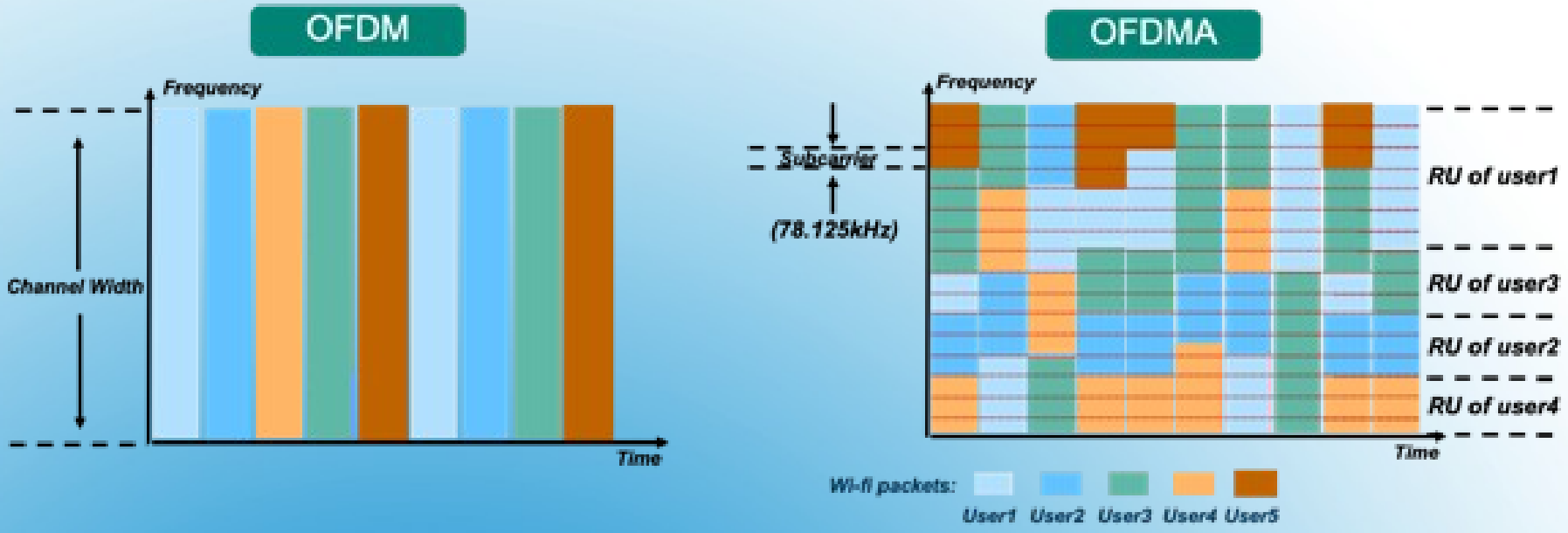
Modulation Changes in 802.11ax

802.11ac	802.11ax
256 QAM	1024 QAM
	
8 bits per symbol	10 bits per symbol

25% Higher Capacity

qorvo

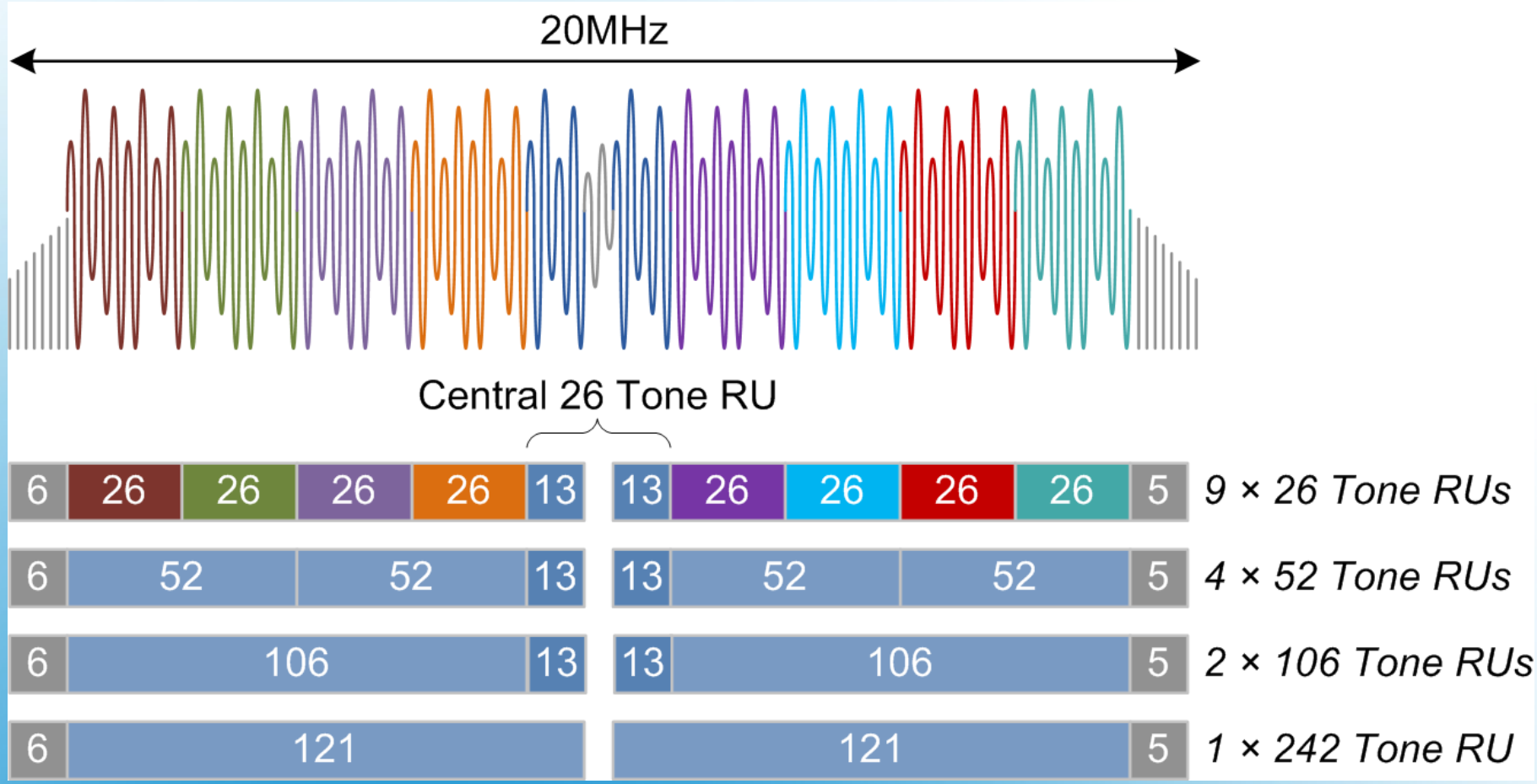
802.11ax: 256QAM to 1024QAM



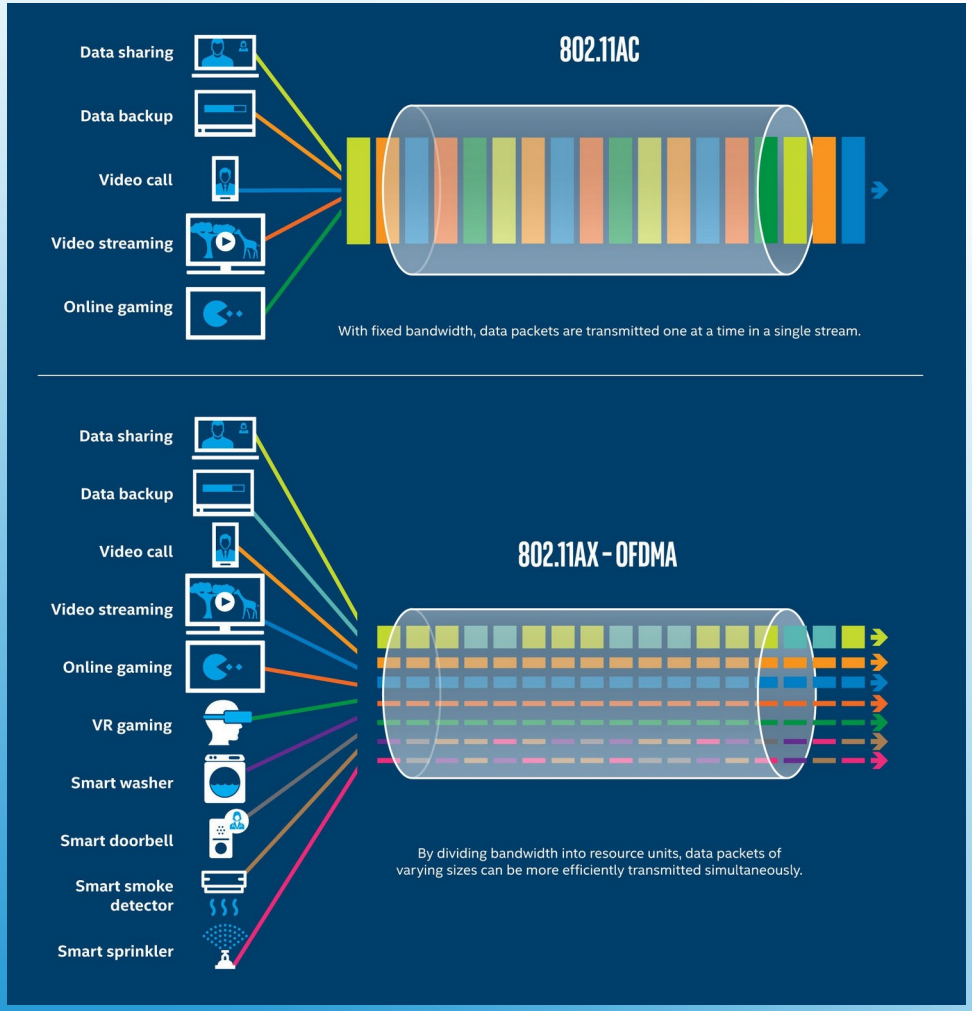
OFDM vs. OFDMA

RU Type	20MHz	40MHz	80MHz	160MHz
26 Tone	9	18	37	74
52 Tone	4	8	16	32
106 Tone	2	4	8	16
242 Tone	1	2	4	8
484 Tone	-	1	2	4
996 Tone	-	-	1	2
1992 Tone	-	-	-	1

WiFi Tones


20MHz
Central 26 Tone RU
6 26 26 26 26 13 13 26 26 26 26 5
9 × 26 Tone RUs
6 52 52 13 13 52 52 5
4 × 52 Tone RUs
6 106 13 13 106 5
2 × 106 Tone RUs
6 121 121 5
1 × 242 Tone RU

WiFi Tones



802.11ac vs 802.11ax

A Little Bit of Marketing

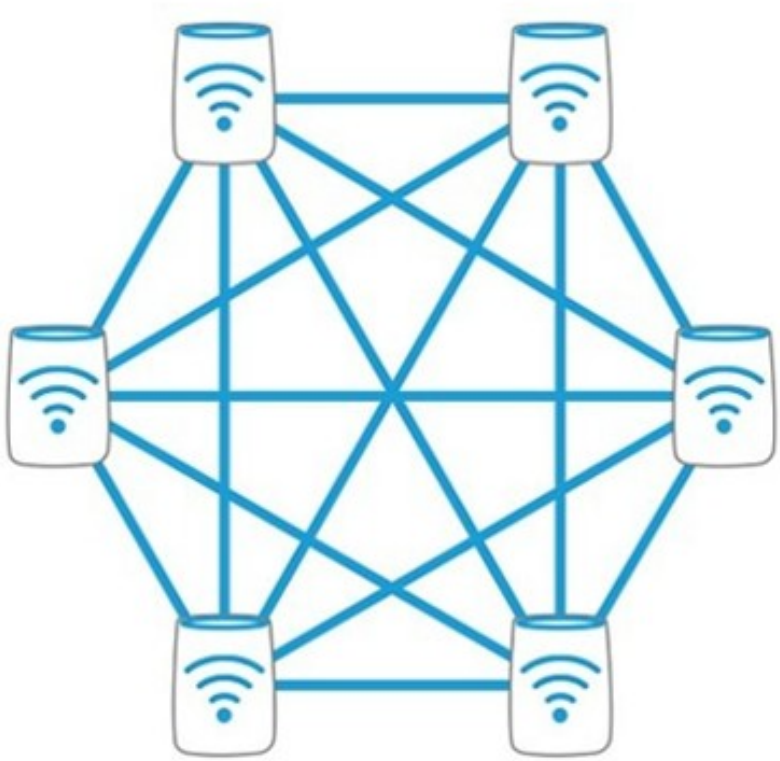
- Support Existing Clients
  - 802.3
  - 802.11b/g
  - 802.11n
  - 802.11ac
- Gigabit Internet
  - Streaming Video / Multiple 1080p Streams
  - Multiple Video Conferences
  - Network for IoT Devices

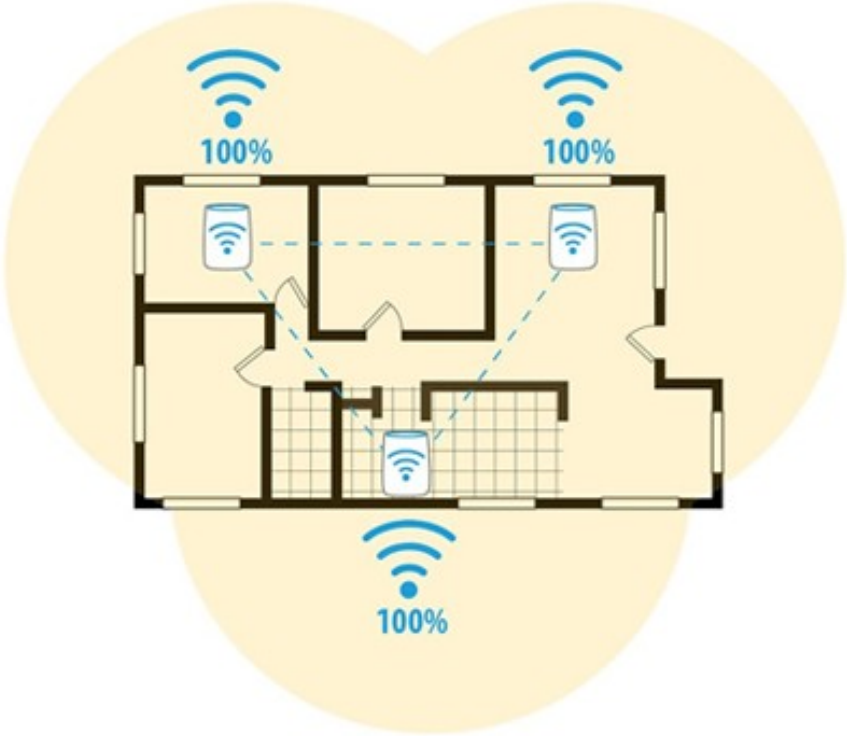
What Did I Need/Want?

- Better WiFi Coverage
- Migration Path to 802.11ax

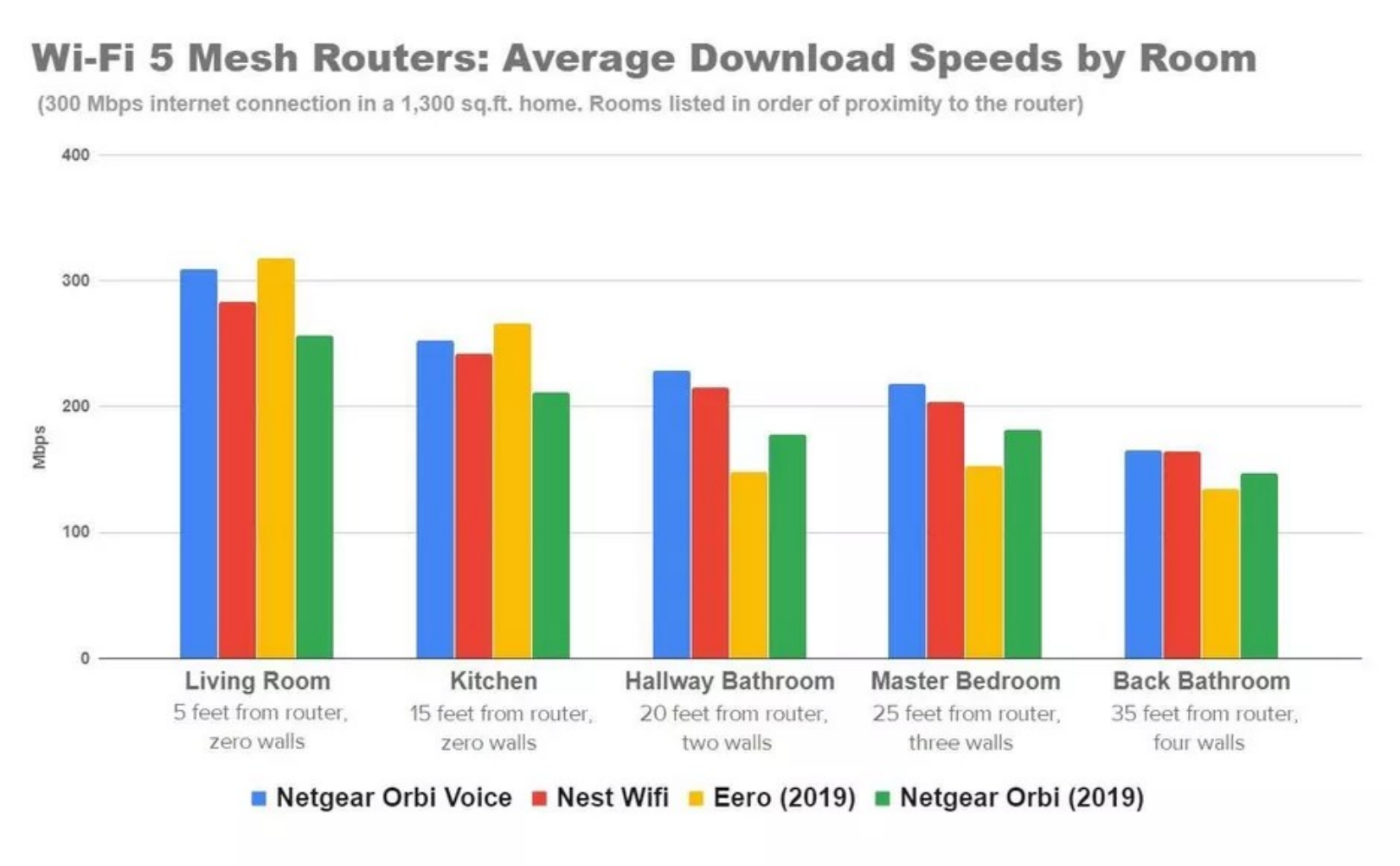
What Did I Need/Want?

Choices, Choices

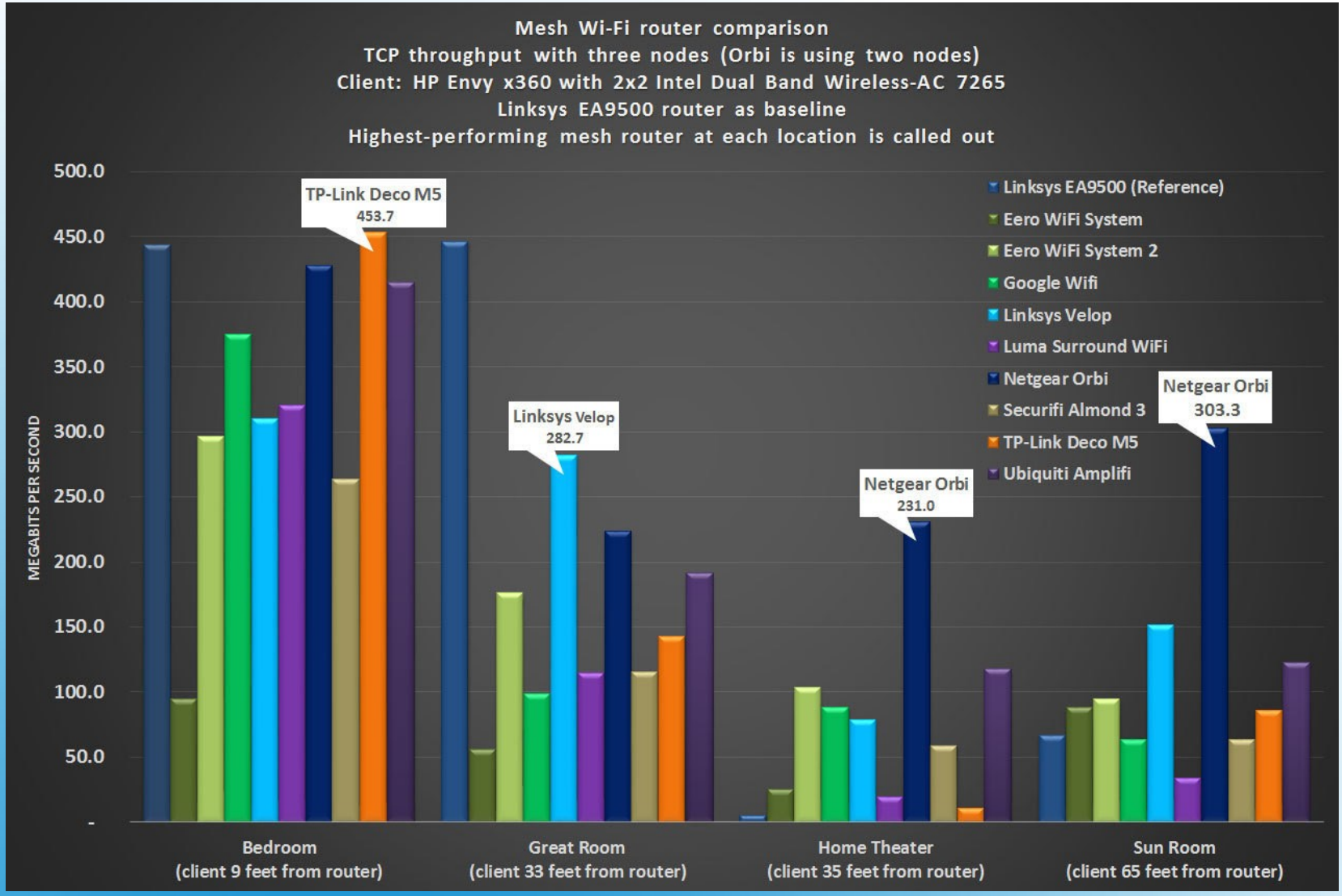




Mesh WiFi

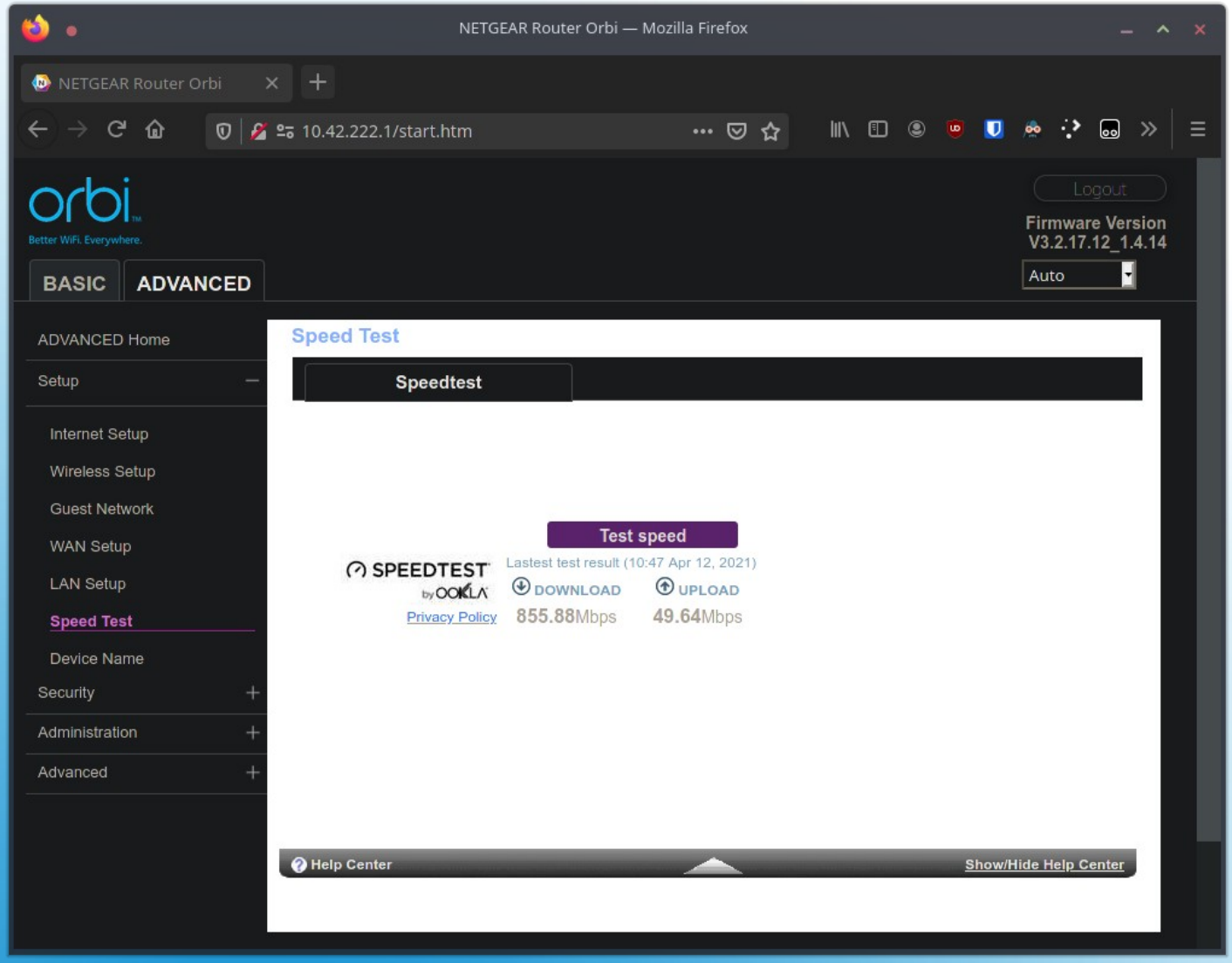

Wi-Fi 5 Mesh Routers: Average Download Speeds by Room
(300 Mbps internet connection in a 1,300 sq.ft. home. Rooms listed in order of proximity to the router)
400
300
200
100
0
Mbps
Living Room
5 feet from router, zero walls
Kitchen
15 feet from router, zero walls
Hallway Bathroom
20 feet from router, two walls
Master Bedroom
25 feet from router, three walls
Back Bathroom
35 feet from router, four walls
Netgear Orbi Voice
Nest Wifi
Eero (2019)
Netgear Orbi (2019)

Mesh WiFi

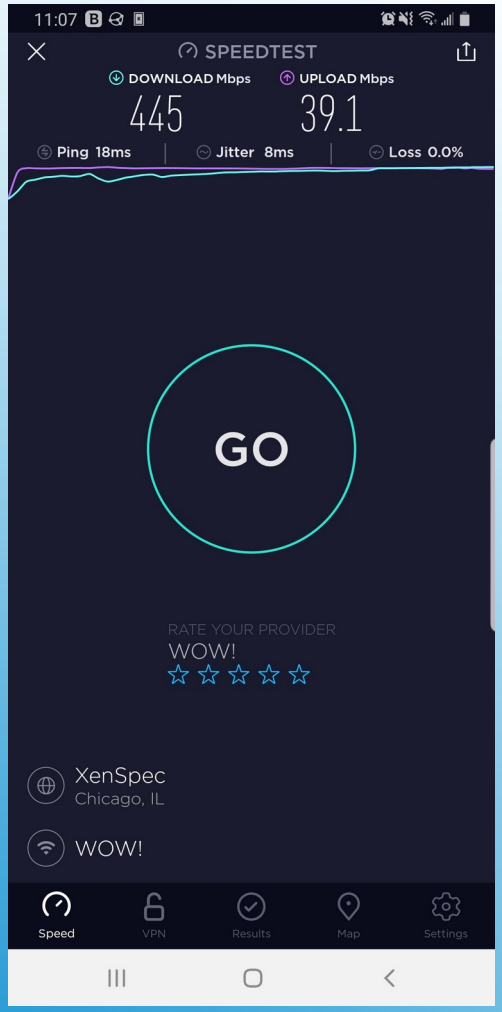

Mesh Wi-Fi router comparison
TCP throughput with three nodes (Orbi is using two nodes)
Client: HP Envy x360 with 2x2 Intel Dual Band Wireless-AC 7265
Linksys EA9500 router as baseline
Highest-performing mesh router at each location is called out
MEGABITS PER SECOND
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
-
TP-Link Deco M5
453.7
Linksys Velop
282.7
Netgear Orbi
231.0
Netgear Orbi
303.3
Linksys EA9500 (Reference)
Eero WiFi System
Eero WiFi System 2
Google Wifi
Linksys Velop
Luma Surround WiFi
Netgear Orbi
Securifi Almond 3
TP-Link Deco M5
Ubiquiti Amplifi
Bedroom
(client 9 feet from router)
Great Room
(client 33 feet from router)
Home Theater
(client 35 feet from router)
Sun Room
(client 65 feet from router)

Mesh WiFi

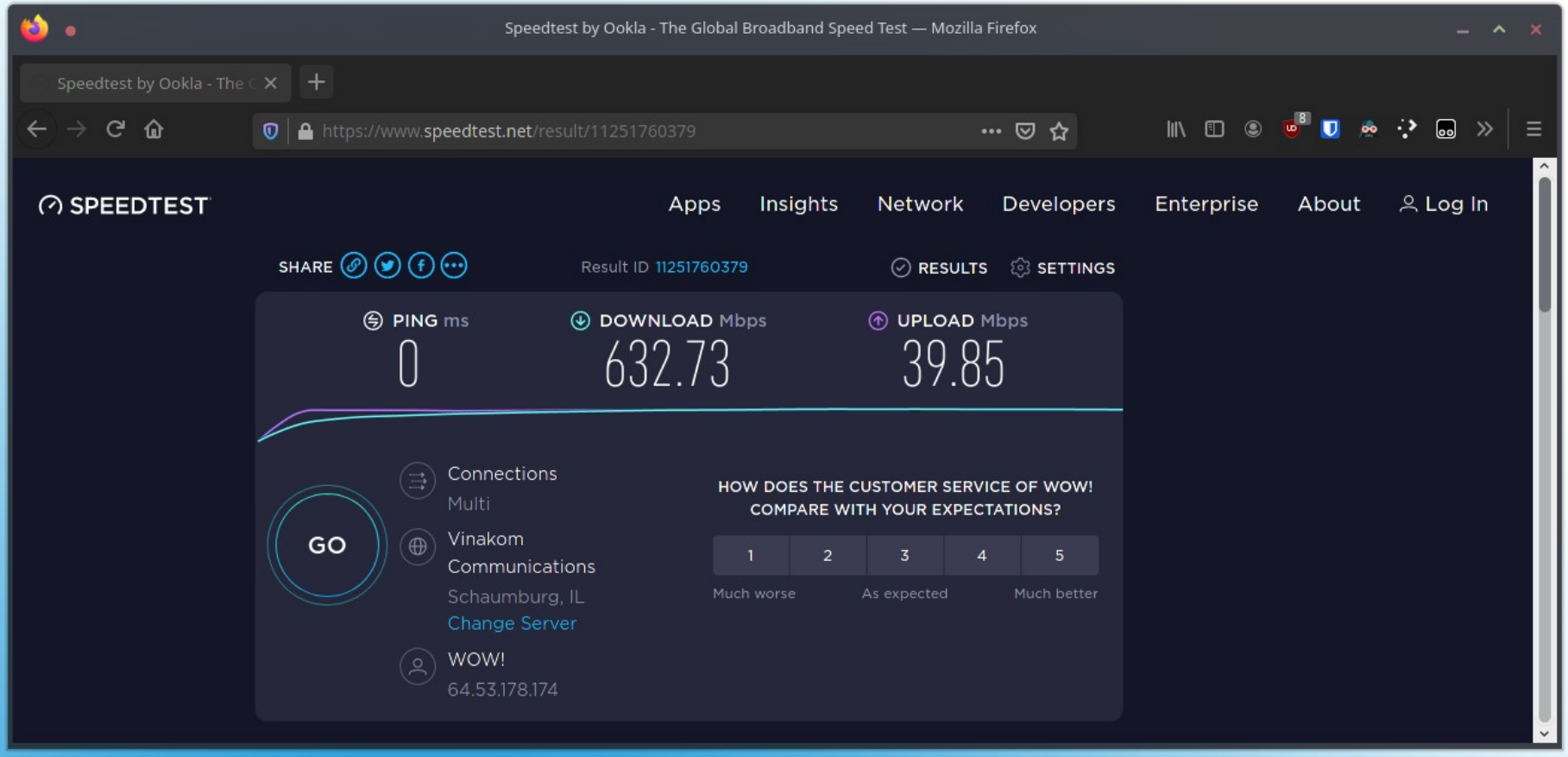
What Did I Get?



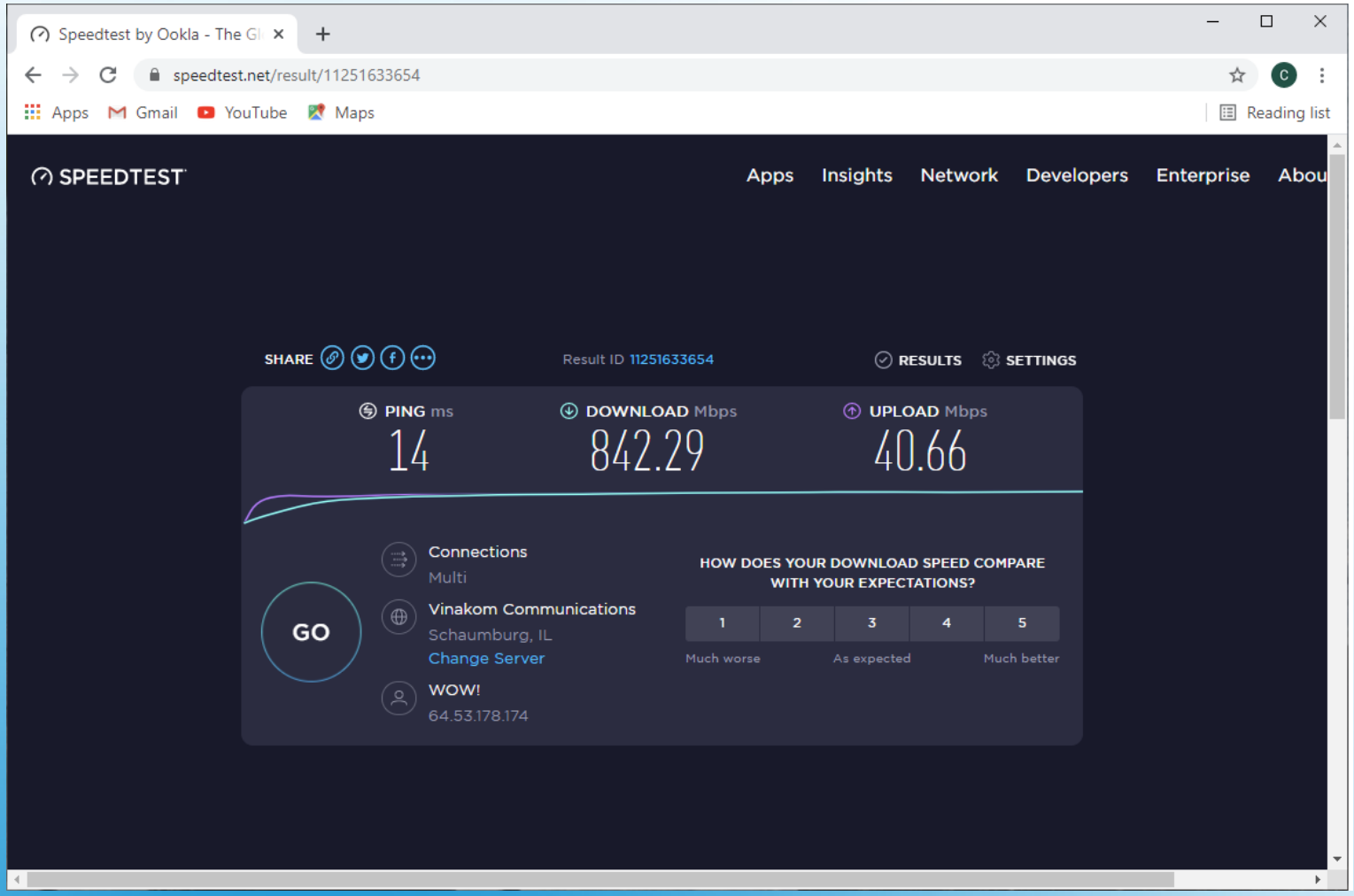
Did It Work?
Netgear Orbi RBK852



Did It Work?
Samsung Galaxy S8+



Did It Work?
Lenovo Yoga c740



Did It Work?
Samsung Book Ion

A Little Bit of Marketing & Federal Regulation

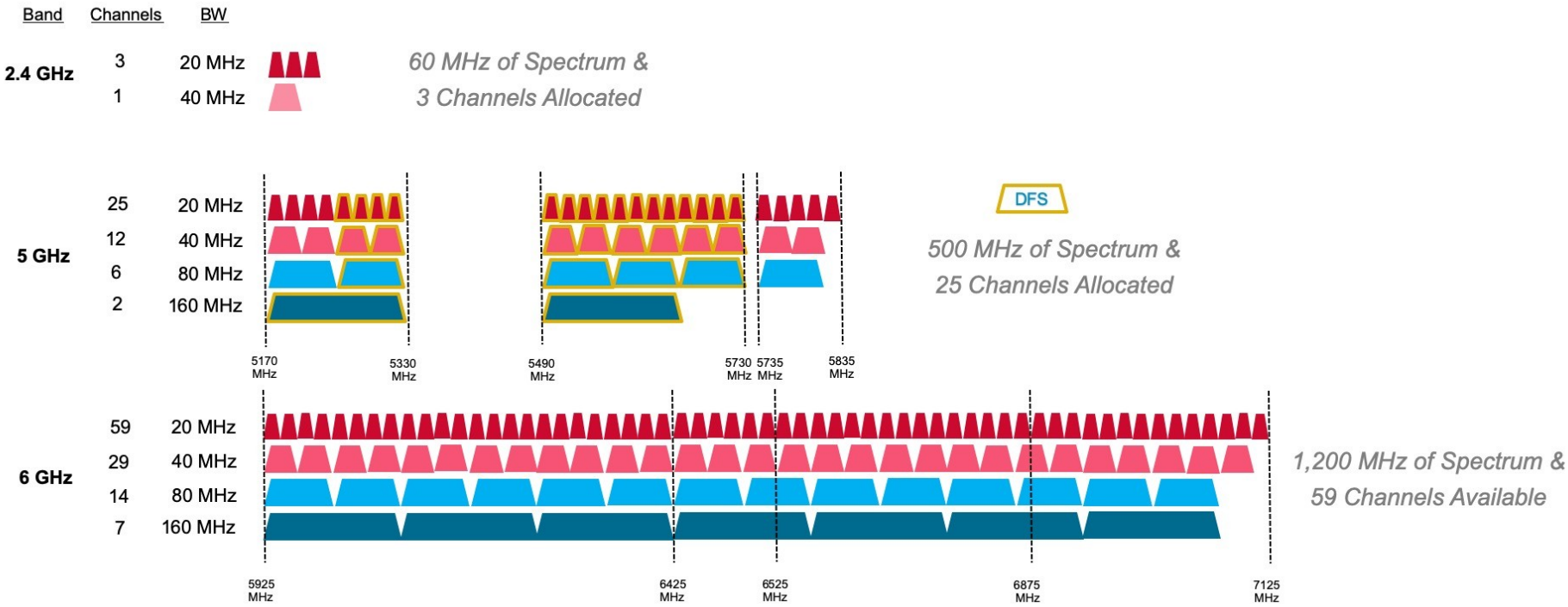
11ax networks

- 6th generation
- 2.4 GHz and 5 GHz
- 80 MHz channels
- 1 Gbps in phones

11ax *EXTENDED to 6 GHz*

- 6th generation ***EXTENDED***
- 2.4 GHz, 5 GHz, and ***6 GHz***
- ***160 MHz*** channels
- ***2 Gbps*** in phones

WiFi 6E

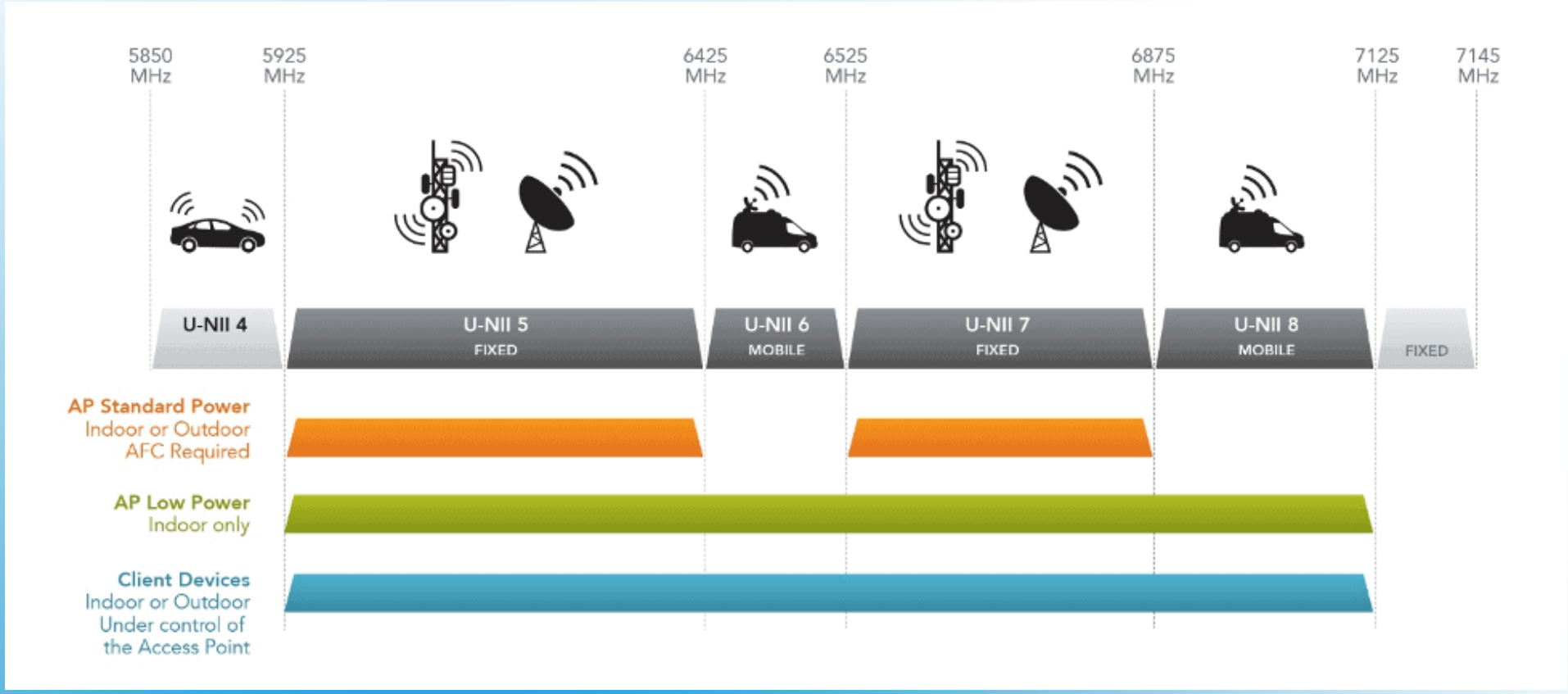


BROADCOM

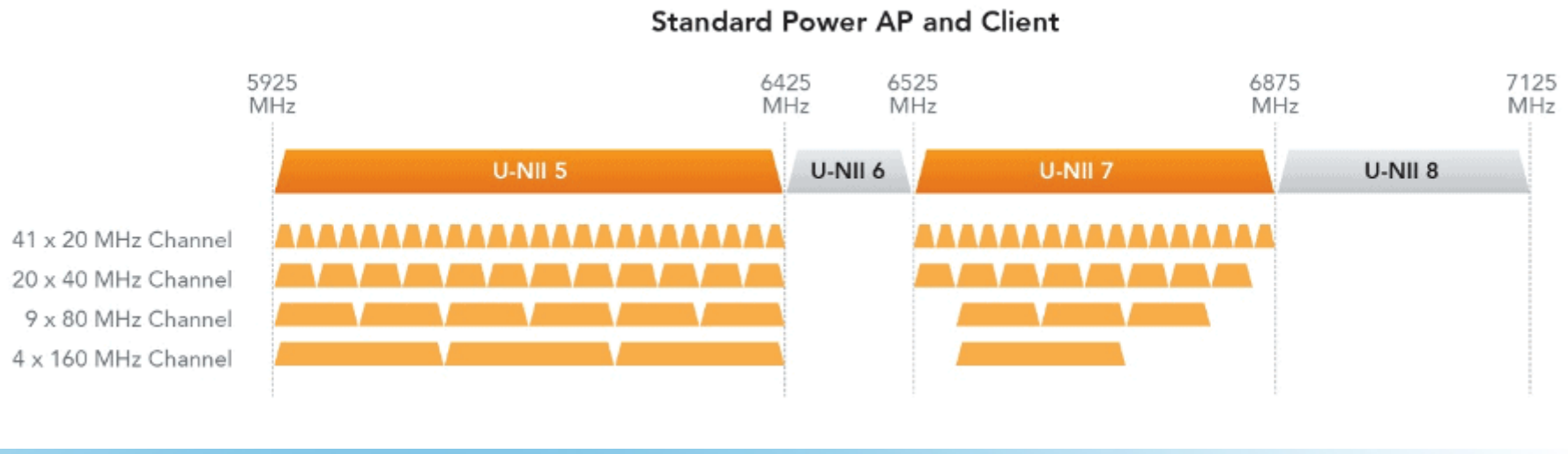
WiFi Spectrum

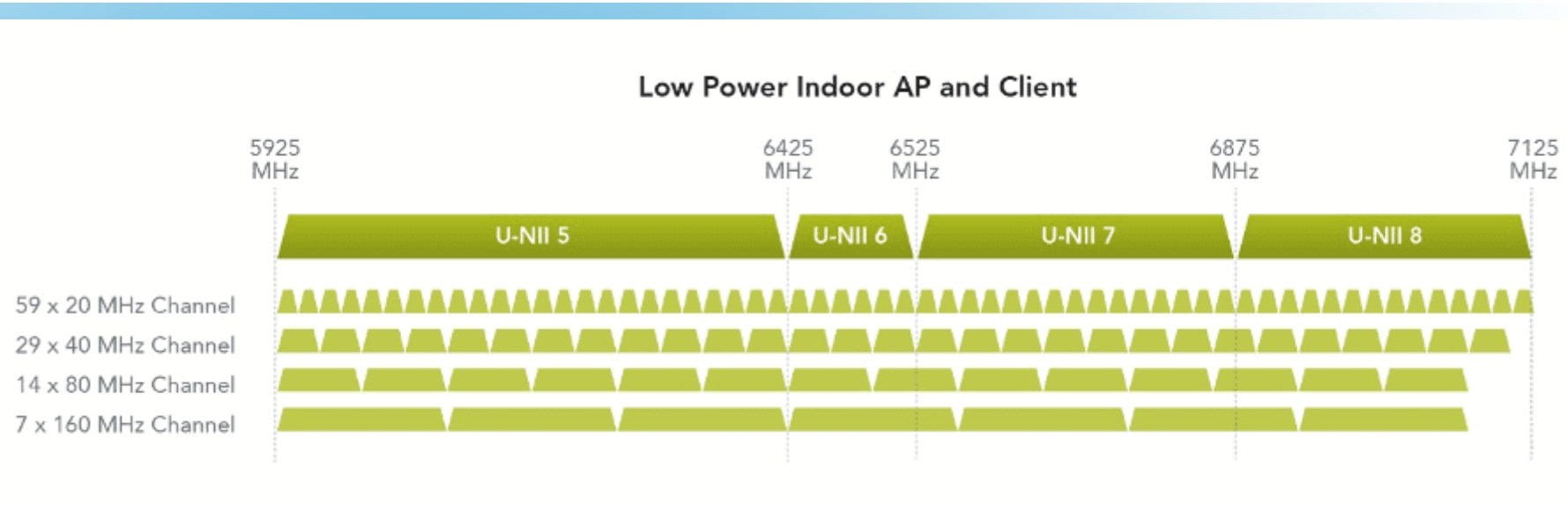
- According to the FCC: “The 6 GHz band is comprised of allocations for Fixed Services, Mobile Services, and Fixed Satellite Services (FSS) across four sub-bands. Fixed microwave service licensees, specifically those operating point-to-point microwave links that support a variety of critical services provided by utilities, commercial and private entities, and public safety agencies, are the largest user group in the 6 GHz band. These fixed microwave service licensees make significant use of the U-NII-5 and U-NII-7 bands, and also operate in relatively smaller numbers in the U-NII-8 band. The band is used to provide backhaul for commercial wireless providers (such as traffic between commercial wireless base stations and wireline networks), and links for coordination of railroad train movements, control of natural gas and oil pipelines, management of electric grids, and long-distance telephone service.” April 23, 2020

6 GHz Incumbent Services



WiFi 6E Incumbent Use





WiFi 6E Power Limitations

6 GHz delivers **1.4 Gbps at 7m** distance even with obstructions

Use Cases

- Residential Multi-AP / mesh networks
- Multiple dwelling unit (MDU) Single-AP networks
- High-density enterprise networks
- Indoor public venues
- Industrial IoT

WiFi 6E Limitation: Indoor Usage

- Routers Are Priced At A Premium
- If you purchased a WiFi 6 router already, your investment may be stranded
- Higher Frequency Means Reduced Coverage
- Lower Power May Mean Reduced Coverage
- WiFi 6 (in Ghz) Is Now N-1
- More products mean increased competition
- Prices will fall for WiFi 6 (in 5GHz)

Should You Invest in WiFi 6E?


QUESTIONS
ANSWERS