WIRELESS LECTURE 1

Outline

- Speed, Wavelength, Frequency Agawal
- Types of Waves
- Radio Frequency Bands
- Propagation Mechanisms
- Radio Propagation Effects
- Free-Space Propagation
- WiFi and Bluetooth comparisons
- Comparison of other wireless communication methods
- IOT

Speed, Wavelength, Frequency

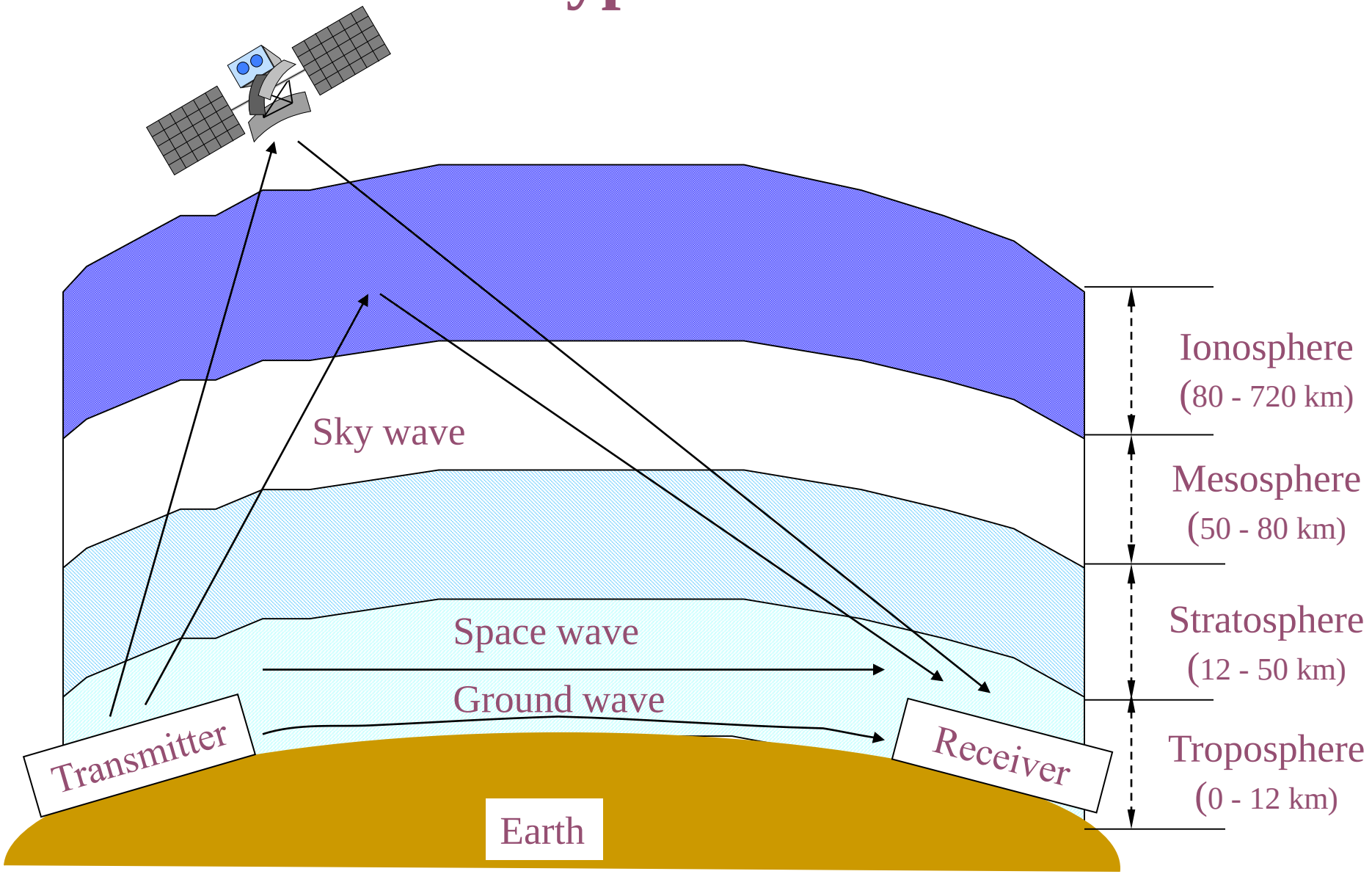
Light speed = Wavelength (meters) x Frequency (Hz)

$= 3 \times 10^8$ m/s = 300,000 km/s

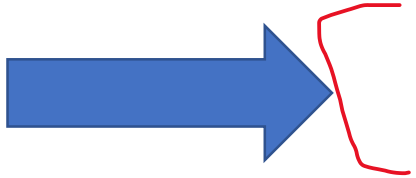
WiFi

System	Frequency	Wavelength
AC current	60 Hz	5,000 km
FM radio	100 MHz	3 m
Cellular	800 MHz	37.5 cm
Ka band satellite	20 GHz	15 mm
Ultraviolet light	10^{15} Hz	10^{-7} m

Types of Waves



Radio Frequency Bands



Classification Band	Initials	Frequency Range	Characteristics
Extremely low	ELF	< 300 Hz	Ground wave
Infra low	ILF	300 Hz - 3 kHz	
Very low	VLF	3 kHz - 30 kHz	
Low	LF	30 kHz - 300 kHz	
Medium	MF	300 kHz - 3 MHz	Ground/Sky wave
High	HF	3 MHz - 30 MHz	Sky wave
Very high	VHF	30 MHz - 300 MHz	Space wave
Ultra high	UHF	300 MHz - 3 GHz	
Super high	SHF	3 GHz - 30 GHz	
Extremely high	EHF	30 GHz - 300 GHz	
Tremendously high	THF	300 GHz - 3000 GHz	

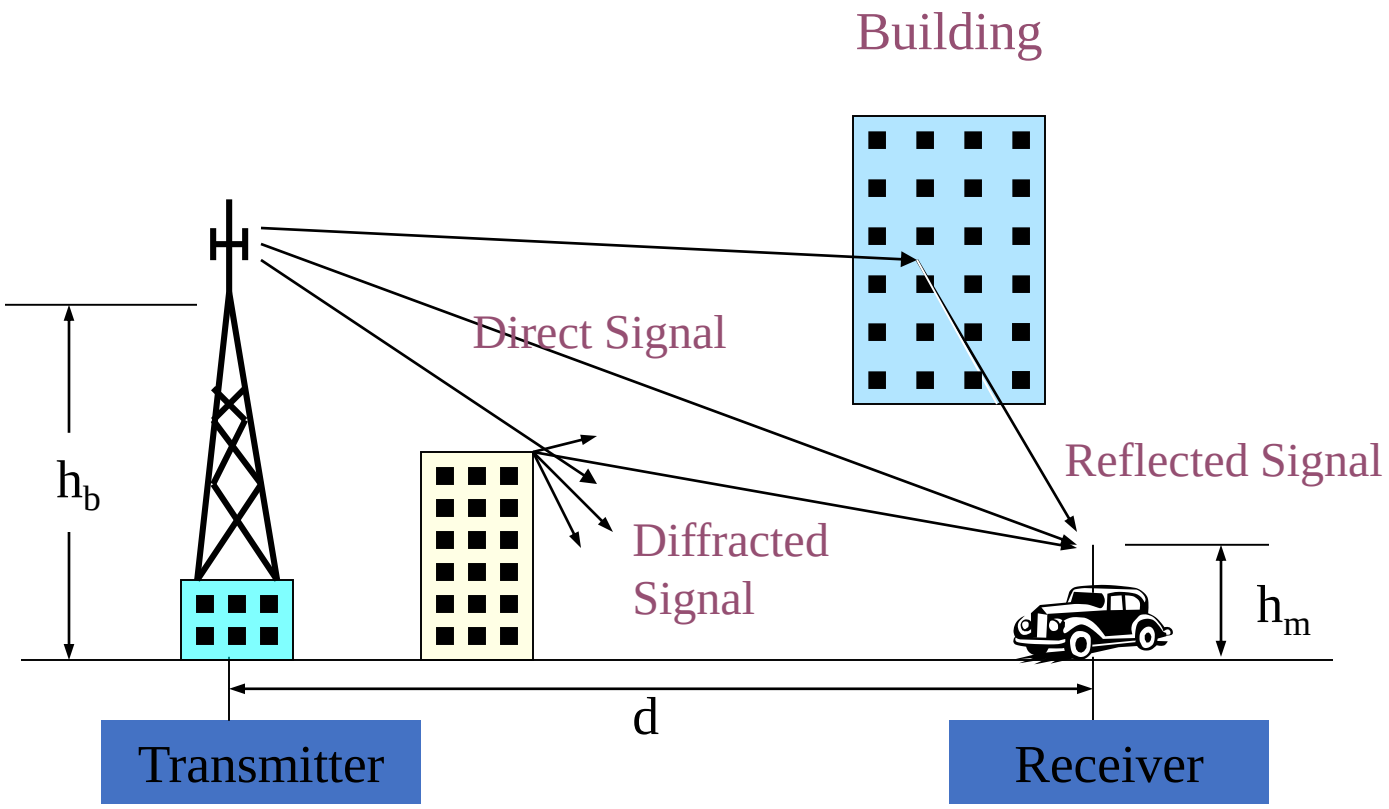
Propagation Mechanisms

- Reflection
  - Propagation wave impinges on an object which is large as compared to wavelength

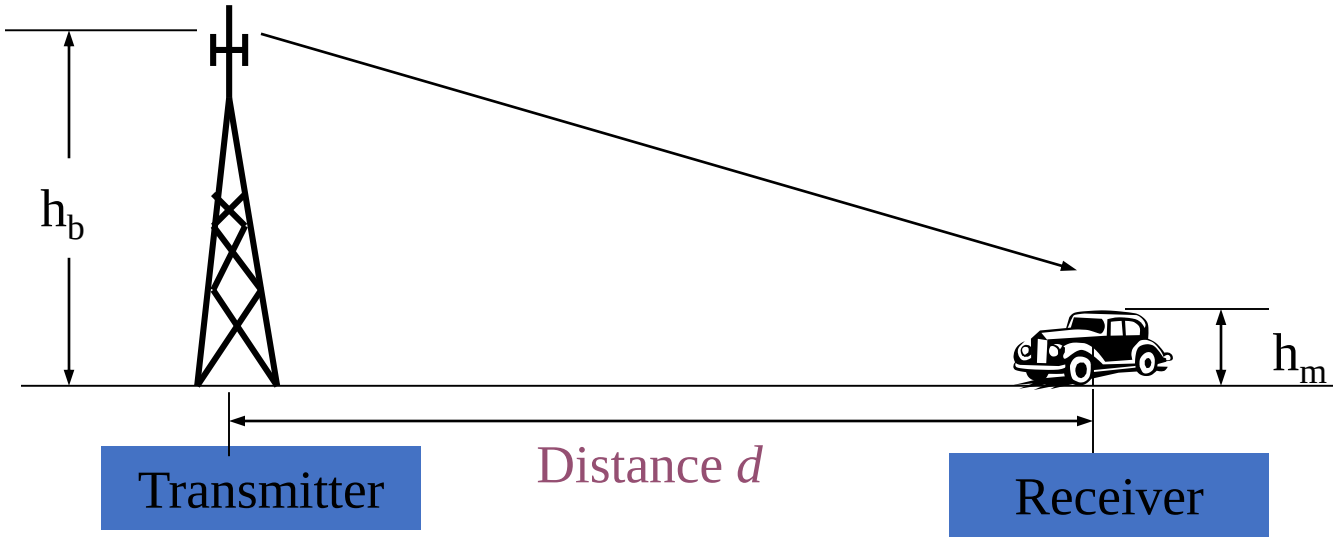
    - e.g., the surface of the Earth, buildings, walls, etc.
- Diffraction
  - Radio path between transmitter and receiver obstructed by surface with sharp irregular edges
  - Waves bend around the obstacle, even when LOS (line of sight) does not exist
- Scattering
  - Objects smaller than the wavelength of the propagation wave

    - e.g. foliage, street signs, lamp posts

Radio Propagation Effects



Free-space Propagation



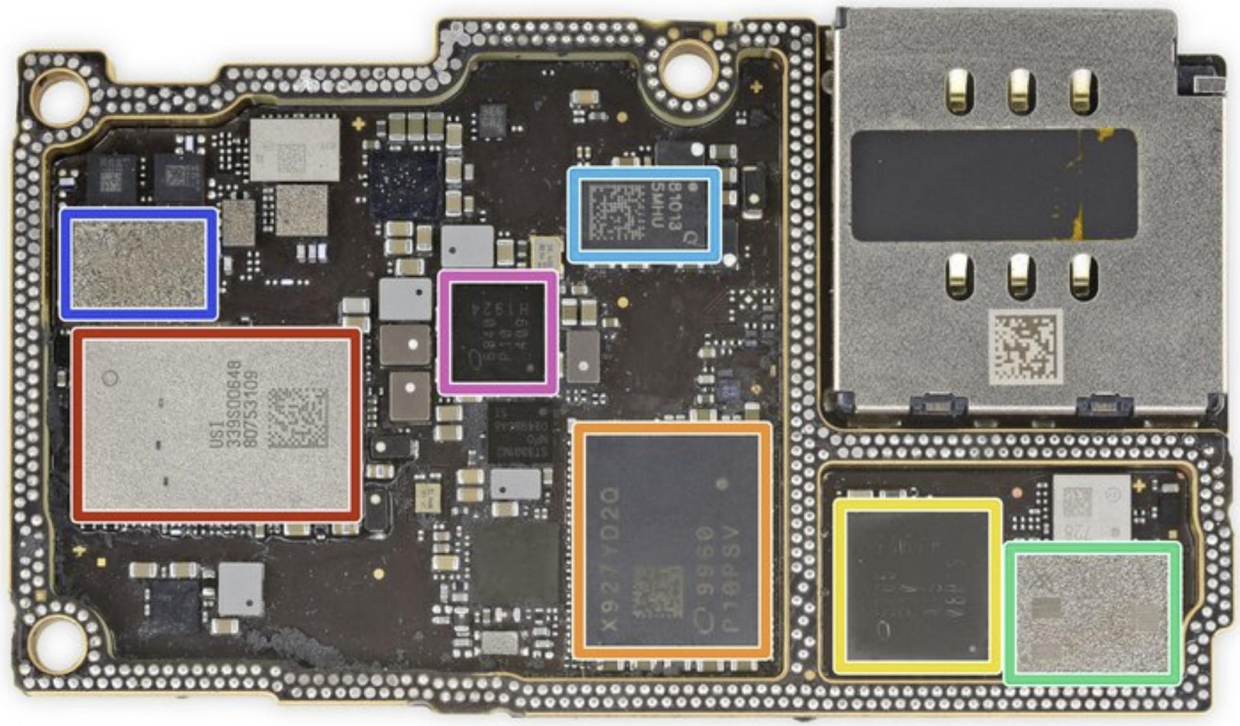
- The received signal power at distance d:

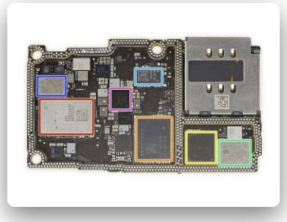
$$P_r = \frac{A_e G_t P_t}{4\pi d^2}$$

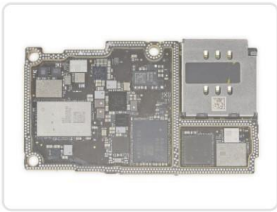
where P_t is transmitting power, A_e is effective area, and G_t is the transmitting antenna gain. Assuming that the radiated power is uniformly distributed over the surface of the sphere.

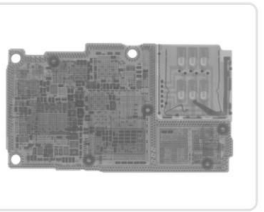
Mobile phones can contain anywhere from four to 13 different **antennas**.
There are at least four radios (transmitters and/or receivers) in **mobile phones** made today: **cellular**, Wi-Fi, Bluetooth, and GPS.
Some **phones** will have three more radios: 802.15.

https://www.ifixit.com/Teardown/iPhone+11+Pro+Max+Teardown/126000





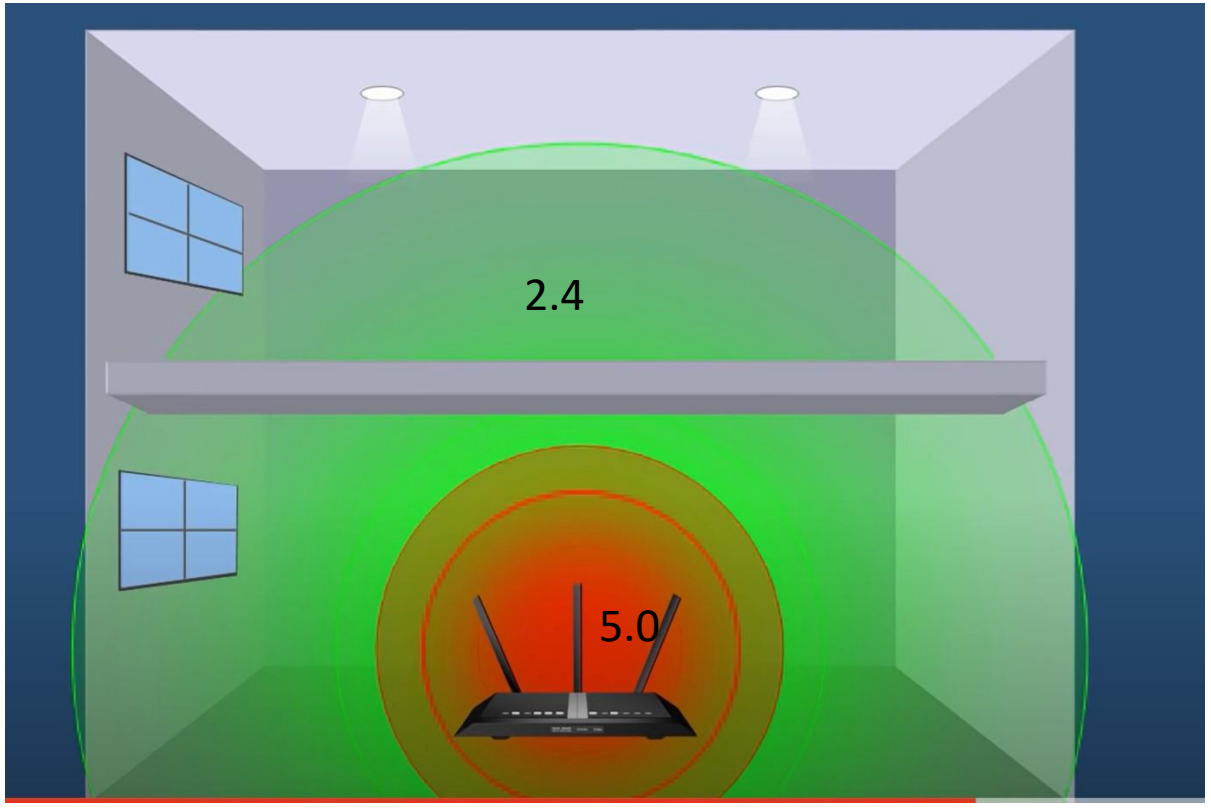




- More chips than you can shake a stick at, but we're shaking as fast as we can. Here's the RF board:
  - Apple/USI 339S00648 WiFi/Bluetooth SoC
  - Intel X927YD2Q (likely XMM7660) modem
  - Intel 5765 P10 A15 08B13 H1925 transceiver
  - Skyworks 78223-17 PAM Power Amplifier
  - 81013 - Qorvo Envelope Tracking
  - Skyworks 13797-19 DRx

2.4 GHz vs 5 GHz WiFi: What is the difference?
2,510,434 views •Nov 28, 2018

https://www.youtube.com/watch?v=J_bf_KE5llQ



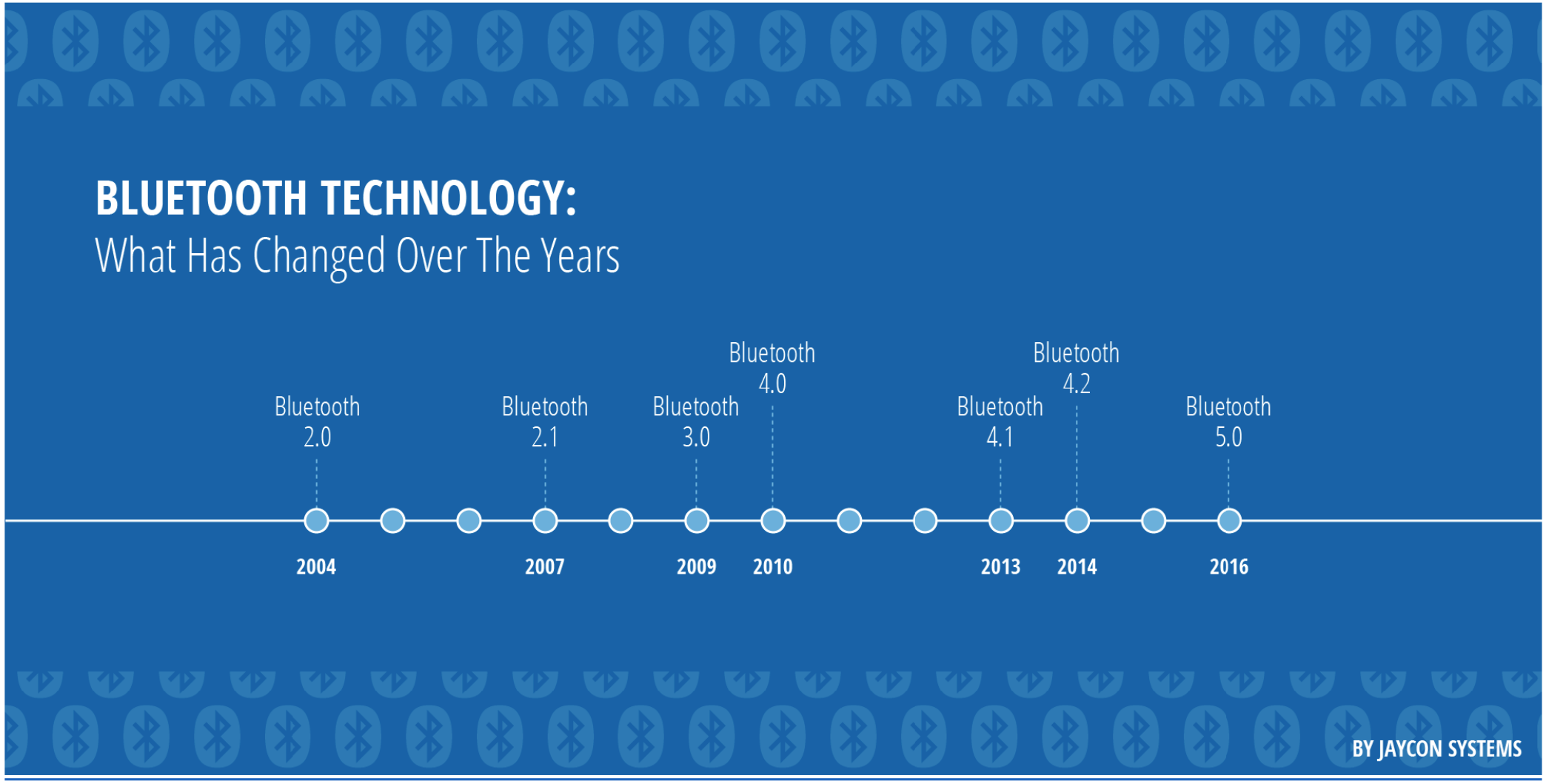


Figure 3. Evolution of Bluetooth technology (2004–16) [4].

Article 25 Years of Bluetooth Technology Sherali Zeadally 1

Table 2. Improvements in Bluetooth versions [14].

Core Version	Issue Year	Major Improvements
1.0	1999	-
1.2	2003	Adaptive frequency hopping, inquiry-based RSSI
2.0	2004	2.1 Mbps peak data rates
2.1	2007	3.0 Mbps peak data rates
3.0	2009	24 Mbps peak data rates
4.0	2010	Lower energy consumption, broadcasting, lower connection latency
4.1	2013	Improved device power management by pairing that allows automatic powering up and down
4.2	2014	Improved security, low energy data packet length extension, link layer privacy
5.0	2016	Higher data rates (48 Mbps), better energy efficiency, higher broadcasting message capacity, larger range and strong point-to-point connection and reliability

Comparison of wireless Technologies

https://predictabledesigns.com/wireless_technologies_bluetooth_wifi_zigbee_gsm_lte_lora_nb-iot_lte-m/

- **Bluetooth Classic**
- **WiFi Direct**
- **Near-Field Communication**
- **Bluetooth Low-Energy (BLE)**
- **Zigbee**
- **Z-Wave**
- **6LoWPAN**
- **WiFi is known as a Local Area Network (LAN) technology**
- **GSM / GPRS, LTE, and Others**

	Power	Speed	Type	Range	Mesh	Frequency
Bluetooth	Low	2-3 Mbps	PAN	50m	No	2.4 GHz
Bluetooth LE	Very low	1 Mbps	PAN	50m	32,767	2.4 GHz
ZigBee	Very low	250 kbps	PAN	100m	65,000	915MHz / 2.4 GHz
Z-Wave	Very low	100 kps	PAN	150m	232	868/908 MHz
6LowPAN / Thread	Very low	Low	PAN	100m	Yes	2.4 GHz
WiFi / WiFi Direct	High	100-250Mbps	LAN	100m+	No	2.4 GHz / 5 GHz
LoRa / LoRaWAN	Low	27 kbps	LPWAN	10km+	No	868 MHz / 915 MHz
GSM/GPRS	Very high	Moderate	WAN	35 km	No	850 MHz / 1.9 GHz
LTE	Very high	High	WAN	Long	No	Various
NB-IOT	Moderate	250kps	LPWAN	20km+	No	Various
LTE-M	Moderate	1 Mbps	LPWAN	Long	No	Various

TO LECTURE 2 More Wireless