IoT Ecosystem using Wireless Technologies

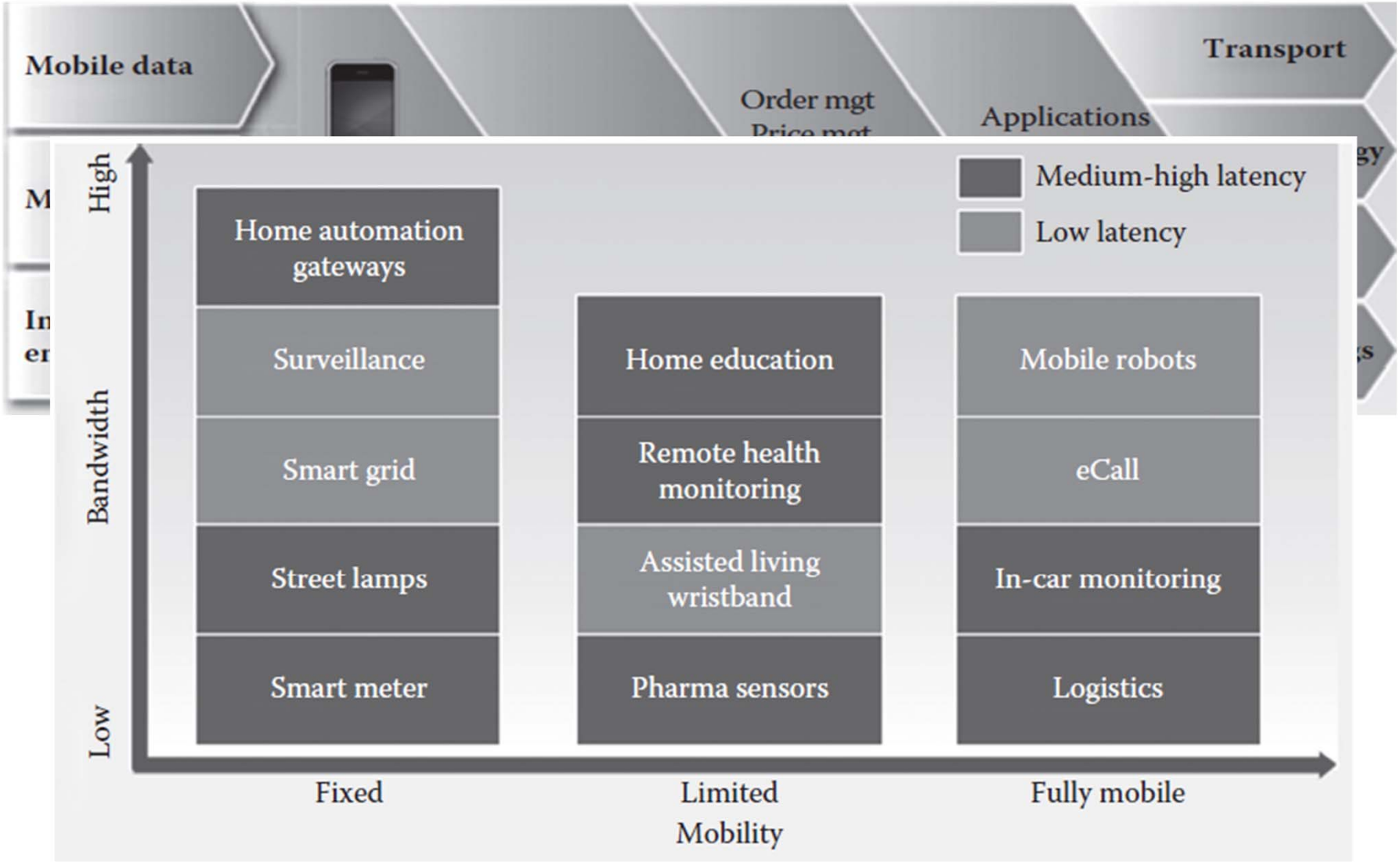
Key Technologies

- 5G
- UWB
- NFC
- Dash7

Communication Protocols

- IEEE 802.15.4
- Zigbee
- 6LoWPAN
- Z-Wave
- Bluetooth
- RFID

Architecture for IoT Device

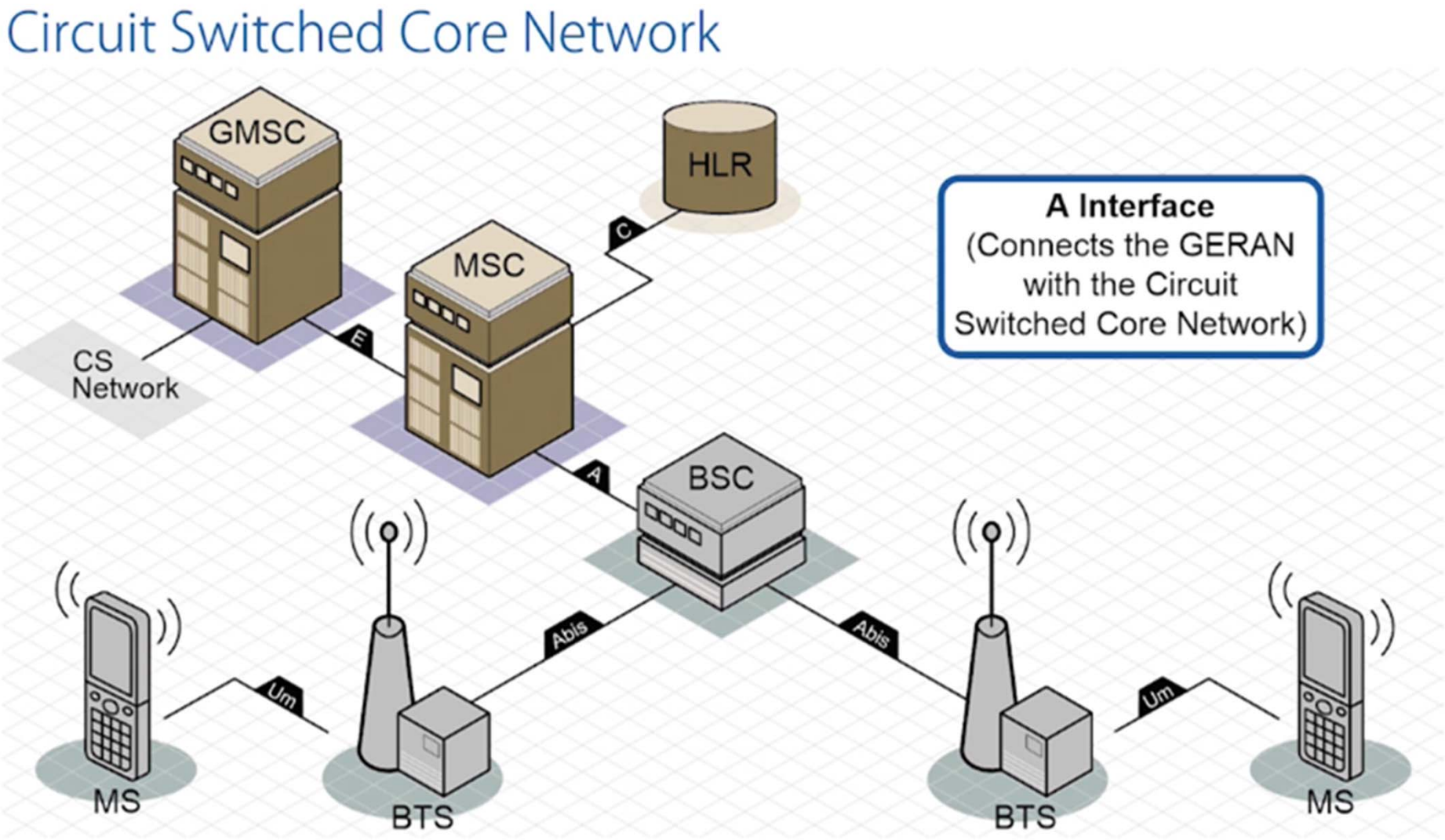


Mobile Networks

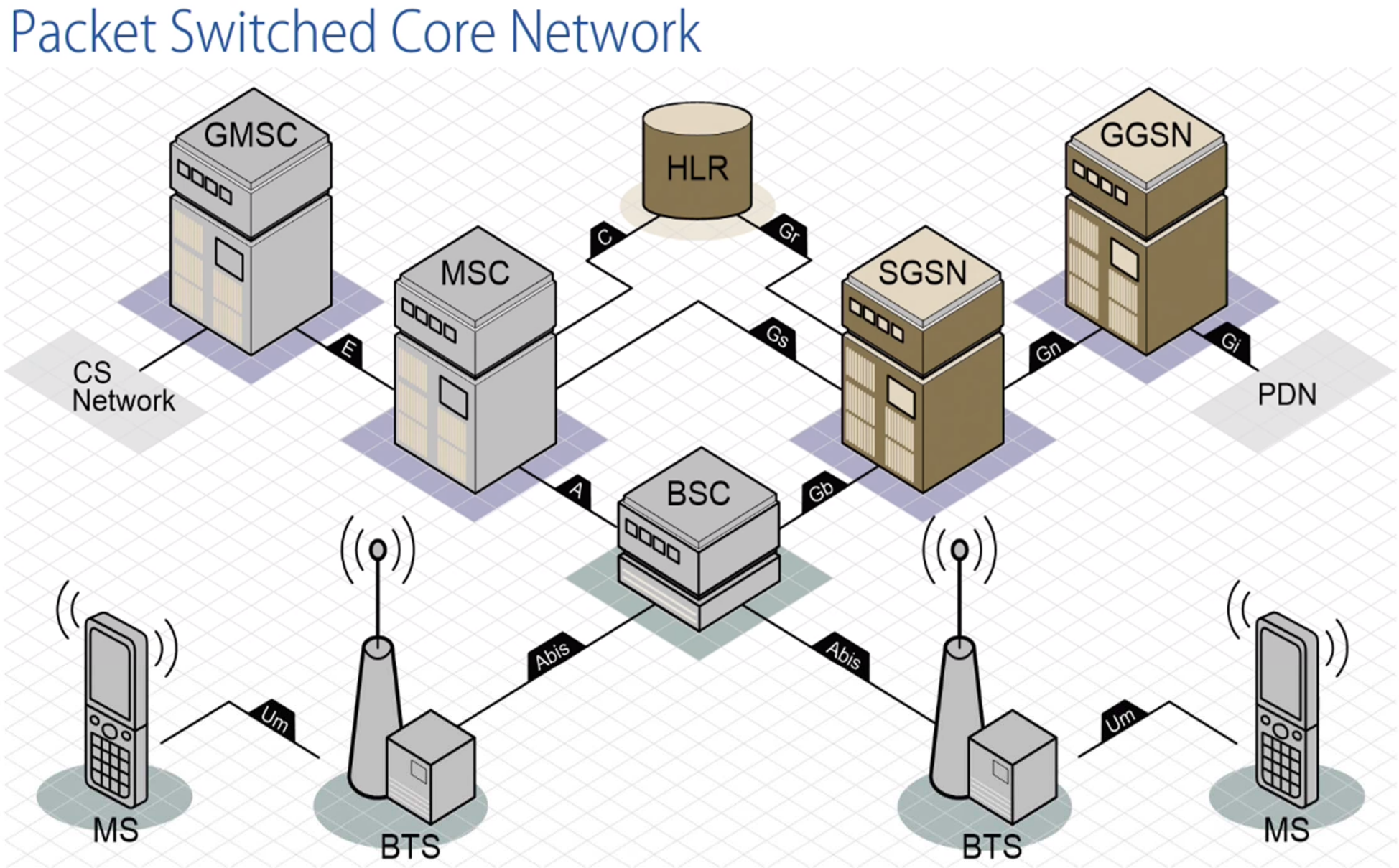
Requirements of a mobile network to support IoT devices

- Support for massive number of devices (10–100 times more device support than the existing networks)
- Support for high data rate (increase the existing data rate 10–100 times)
- Reduce the latency between end-to-end devices; ideally, the latency should be less than 5 ms
- Provide consistent quality of experience (QoE)
- Reduce capital and operations cost

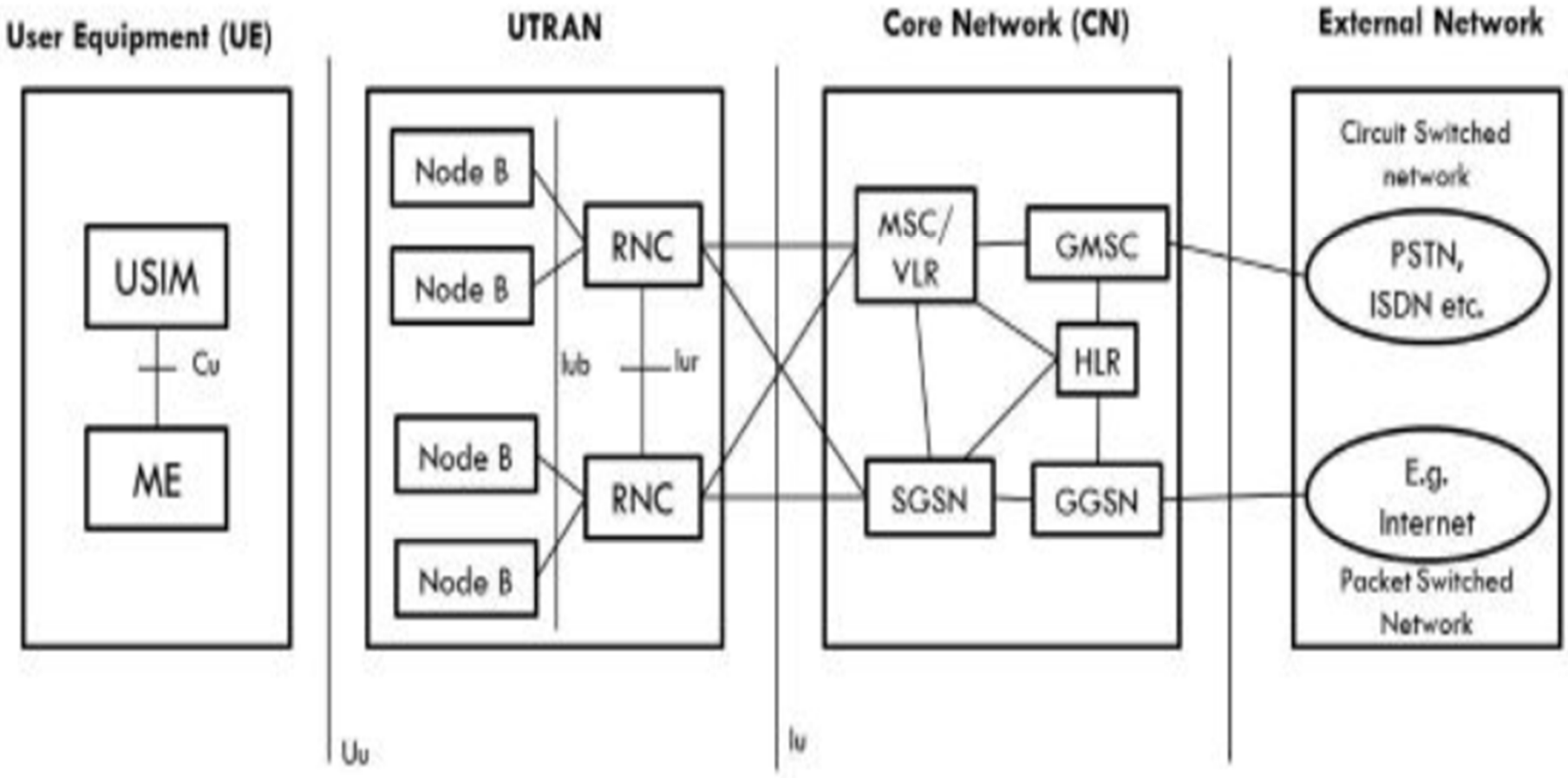
2G Architecture



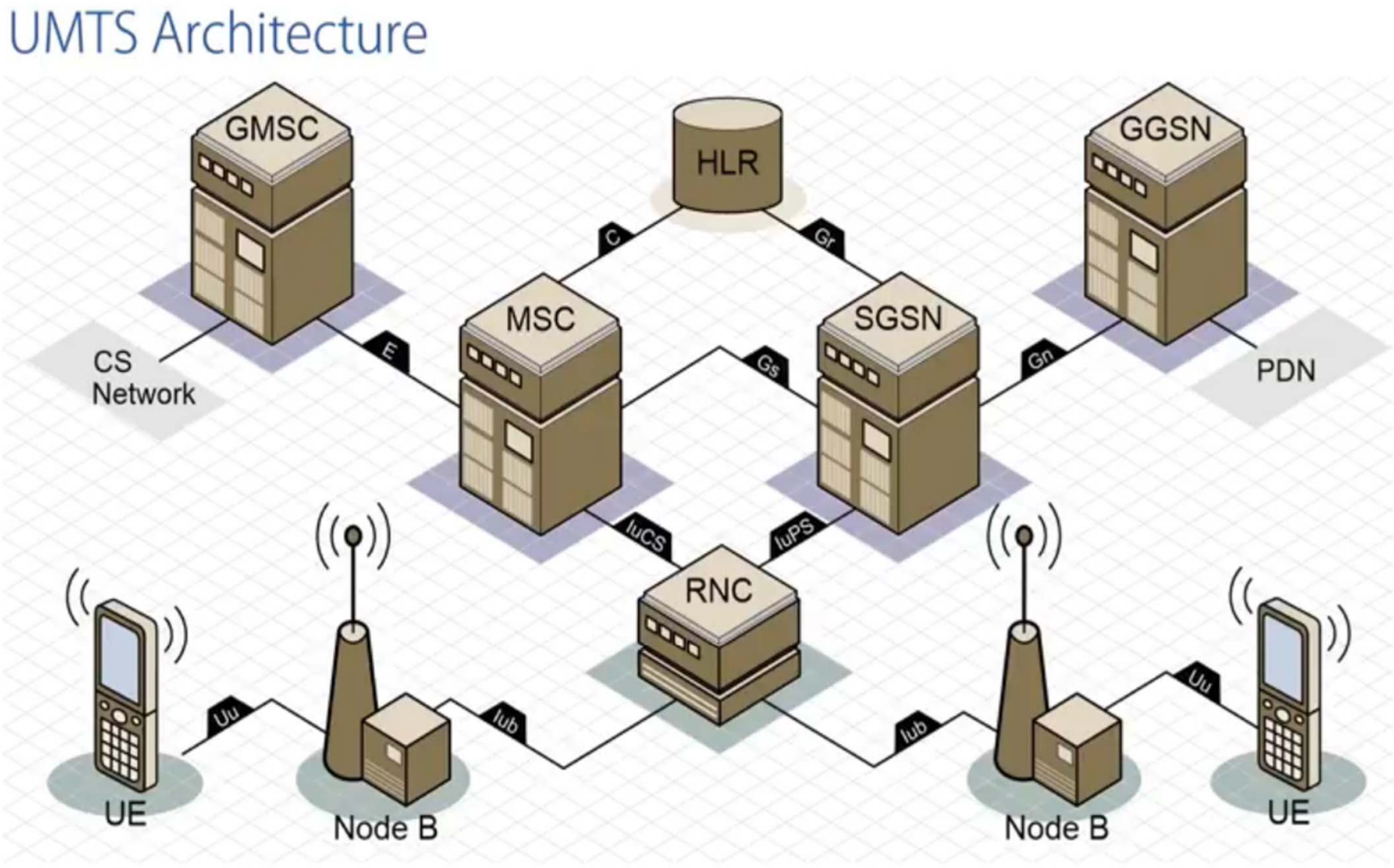
2G Architecture



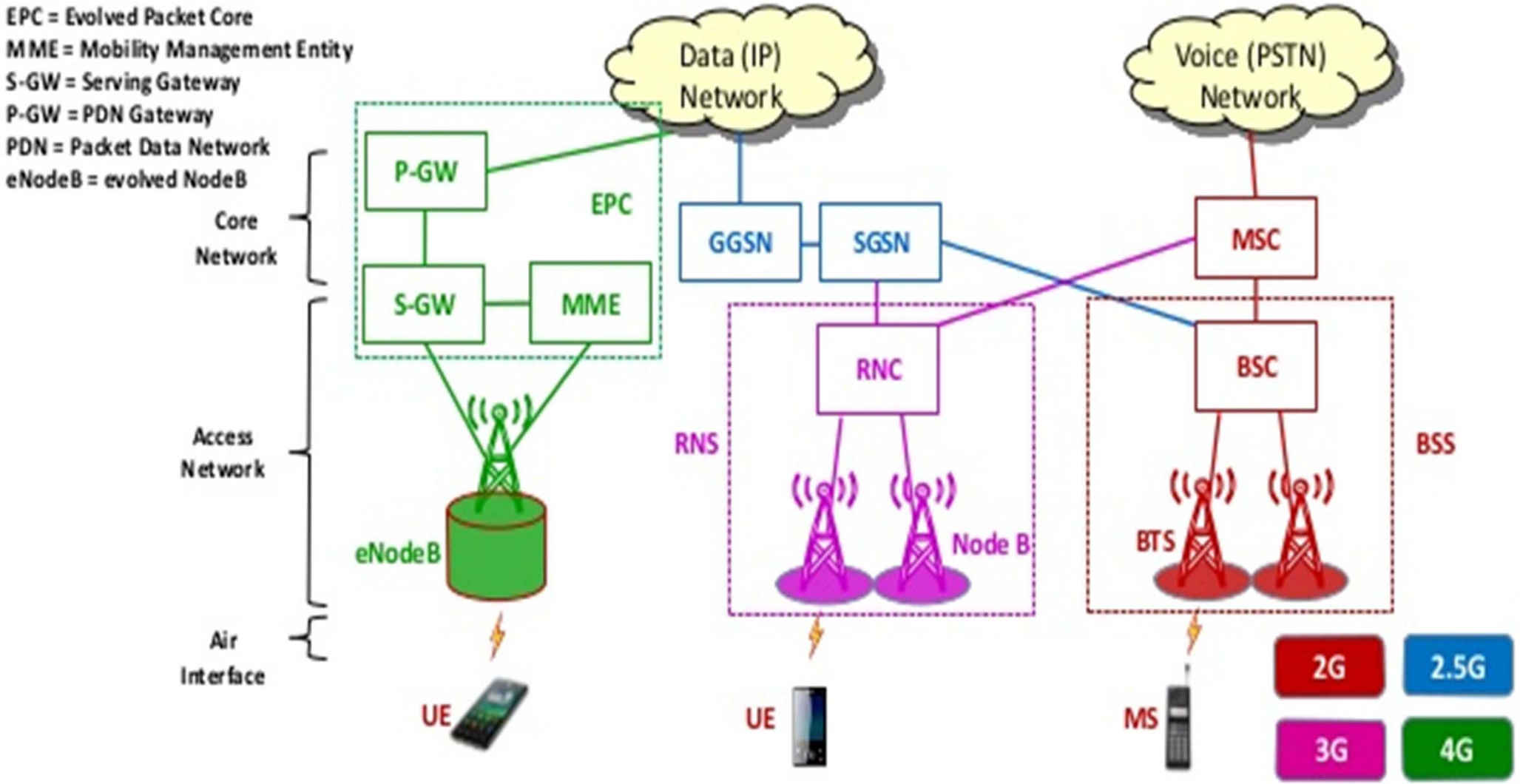
3G Architecture



3G Architecture - UMTS



The '4G' LTE Network Architecture



Frequency Bands in India

7L%LXR .?

- >55%R M¡
- 6=55%R M¡

8L%ZR YX4\ HIR F.?

- >55%R M¡
- 7655%R M¡

9L%QYJ.?

- =:5%R M¡%Gfsi%:.
- 6=55%R M¡%Gfsi%8.
- 7855%R M¡%Gfsi%95.
- 7:55%R M¡%Gfsi%96.
- 7;55%R M¡%Gfsi%8=.

:L%SW.?

- Ymj%:L%gfsix%fqtlhfyji%ktw%zxj%ns%Nsinf%| tzqi%y~umfqt~%nshqzij%f%r n}%tk%r ni2gfsi%fsi%mnlm2gfsi%kwjvzjshnjx3
- Xzg2;%LM¡%gfsix%-j3l3l%83:%LM¡.
- r r \ f{j%gfsix%-j3l3l%7;%LM¡.

5G NR *is equivalent to how the mobile communications industry has used LTE to describe 4G technology or UMTS to describe 3G technology.*

What is 5G New Radio?

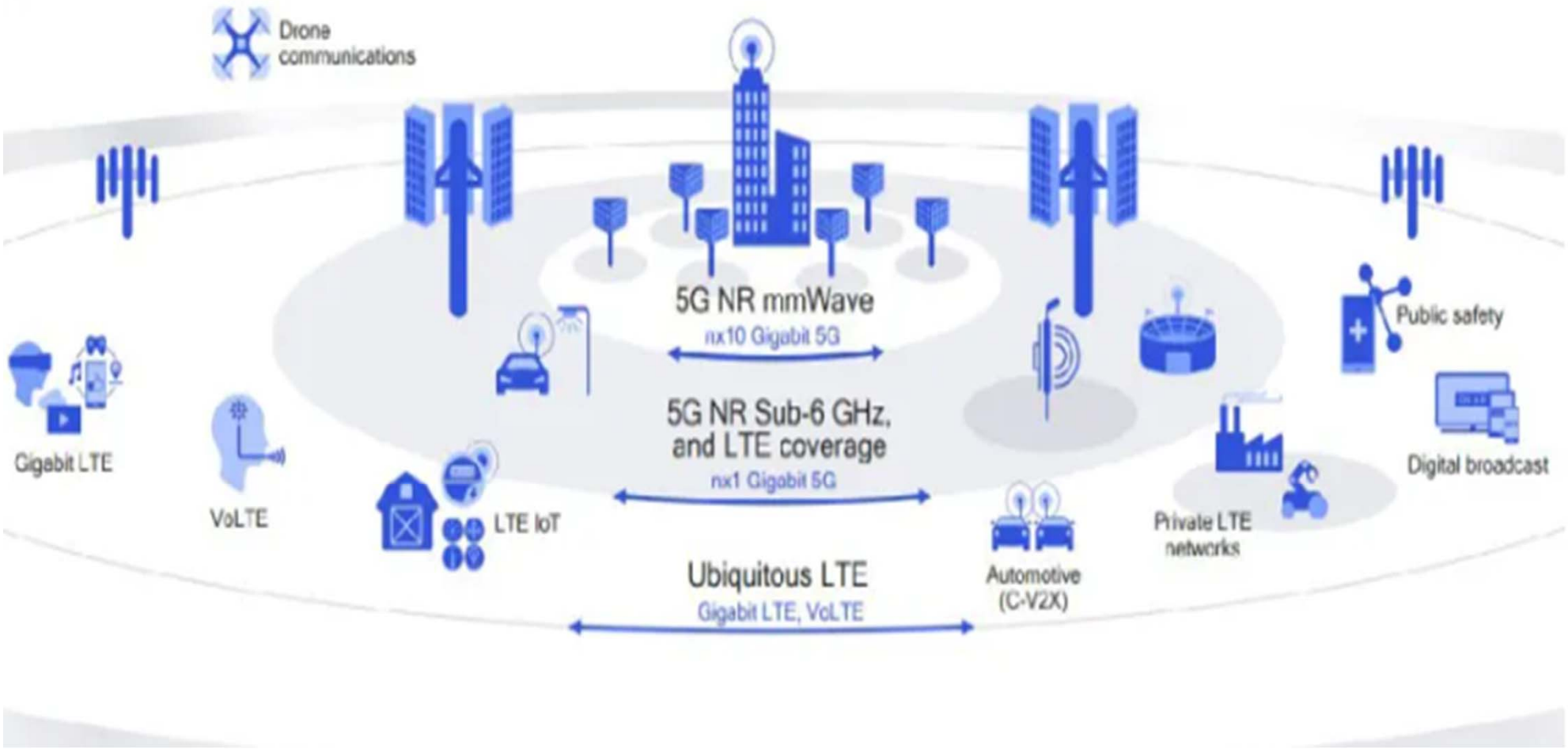
New Radio (NR) is the wireless standard that will become the foundation for the next generation 5G of mobile networks.

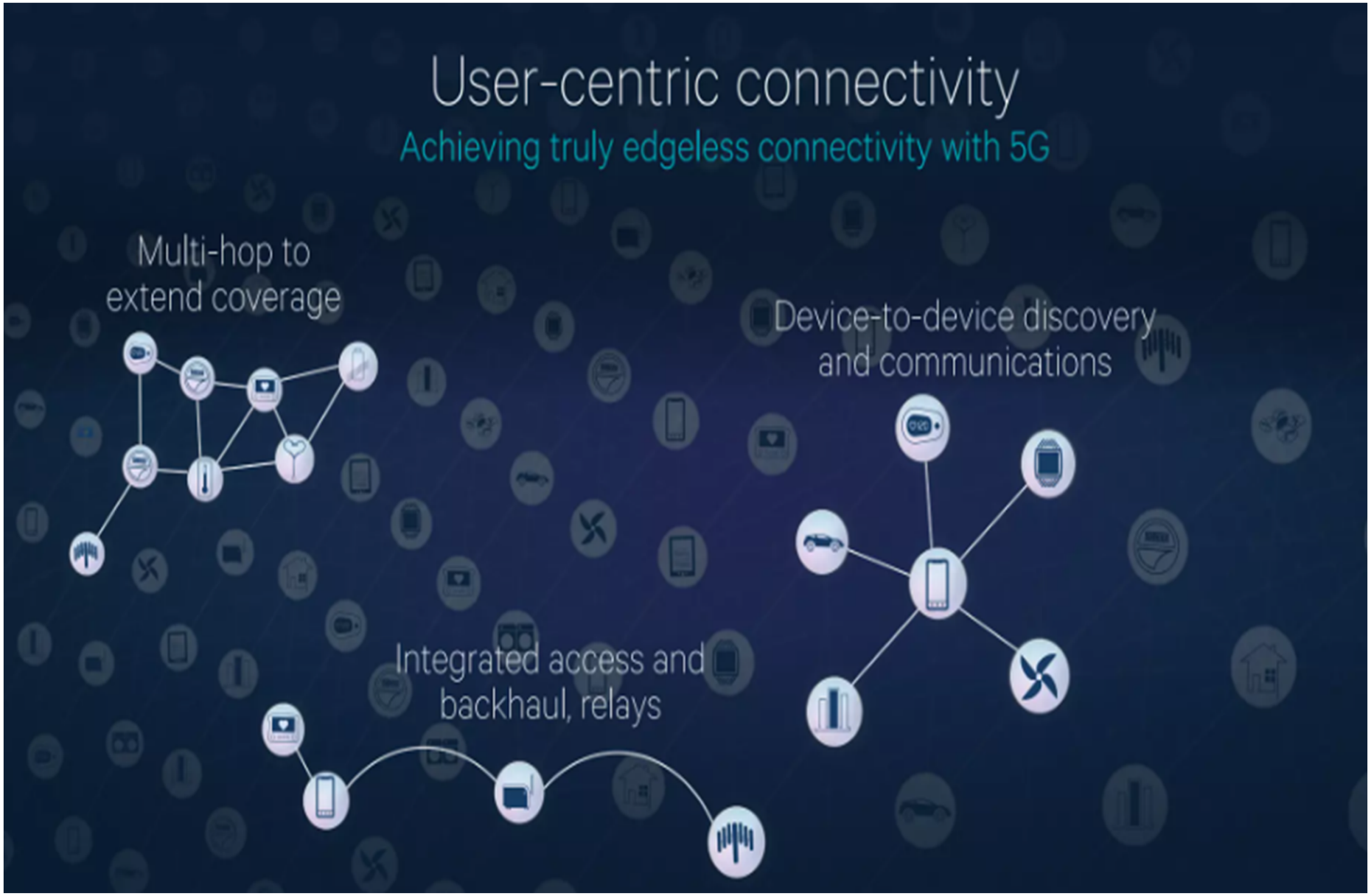
5G NR aims to make wireless broadband same as of wireline with the **fiber-like** performance at a significantly lower cost-per-bit.

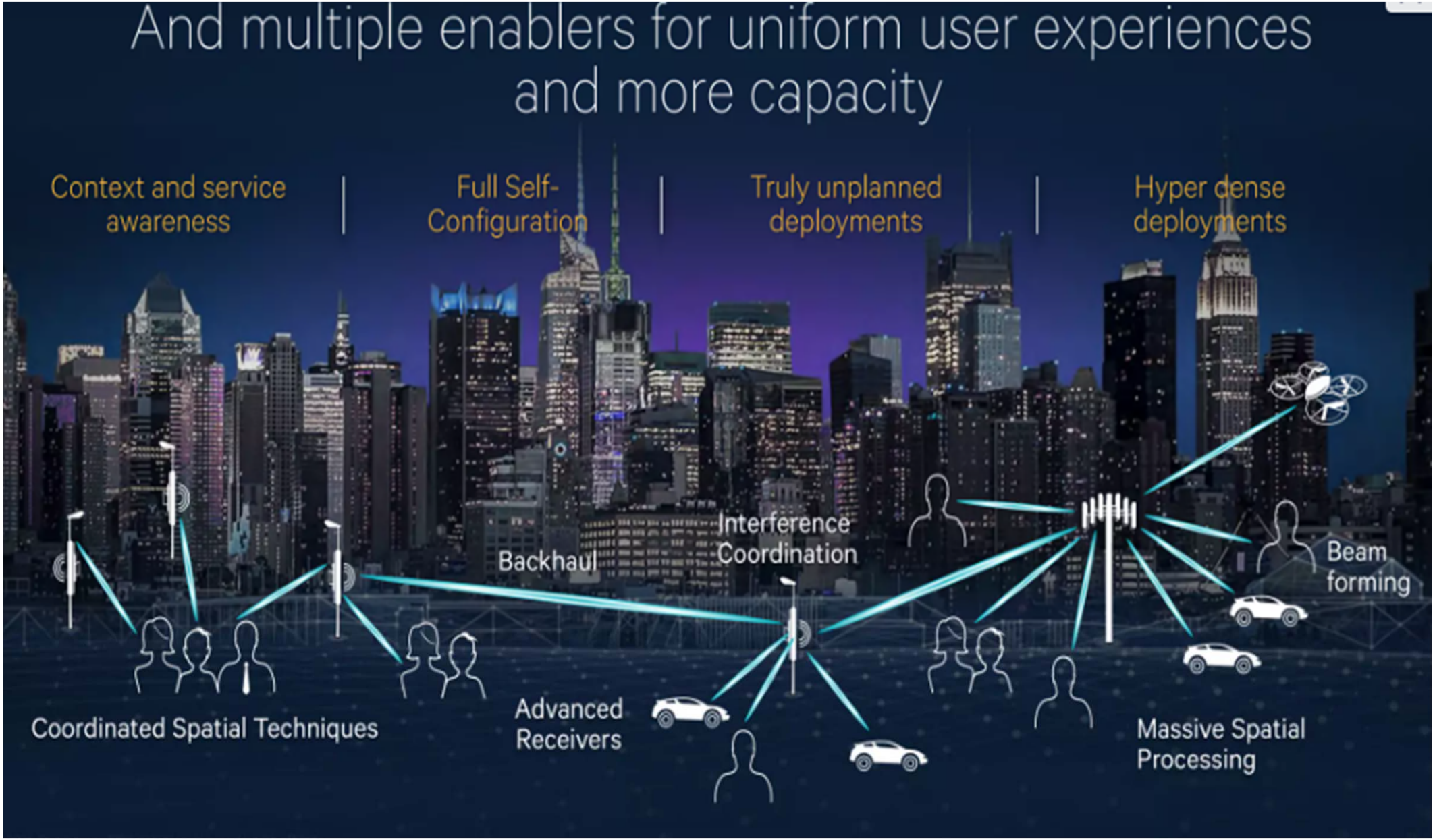
In legacy 3G and 4G connected people, whereas future **5G NR** will connect everything means it will be connecting our smartphones, cars, meters, wearable etc.

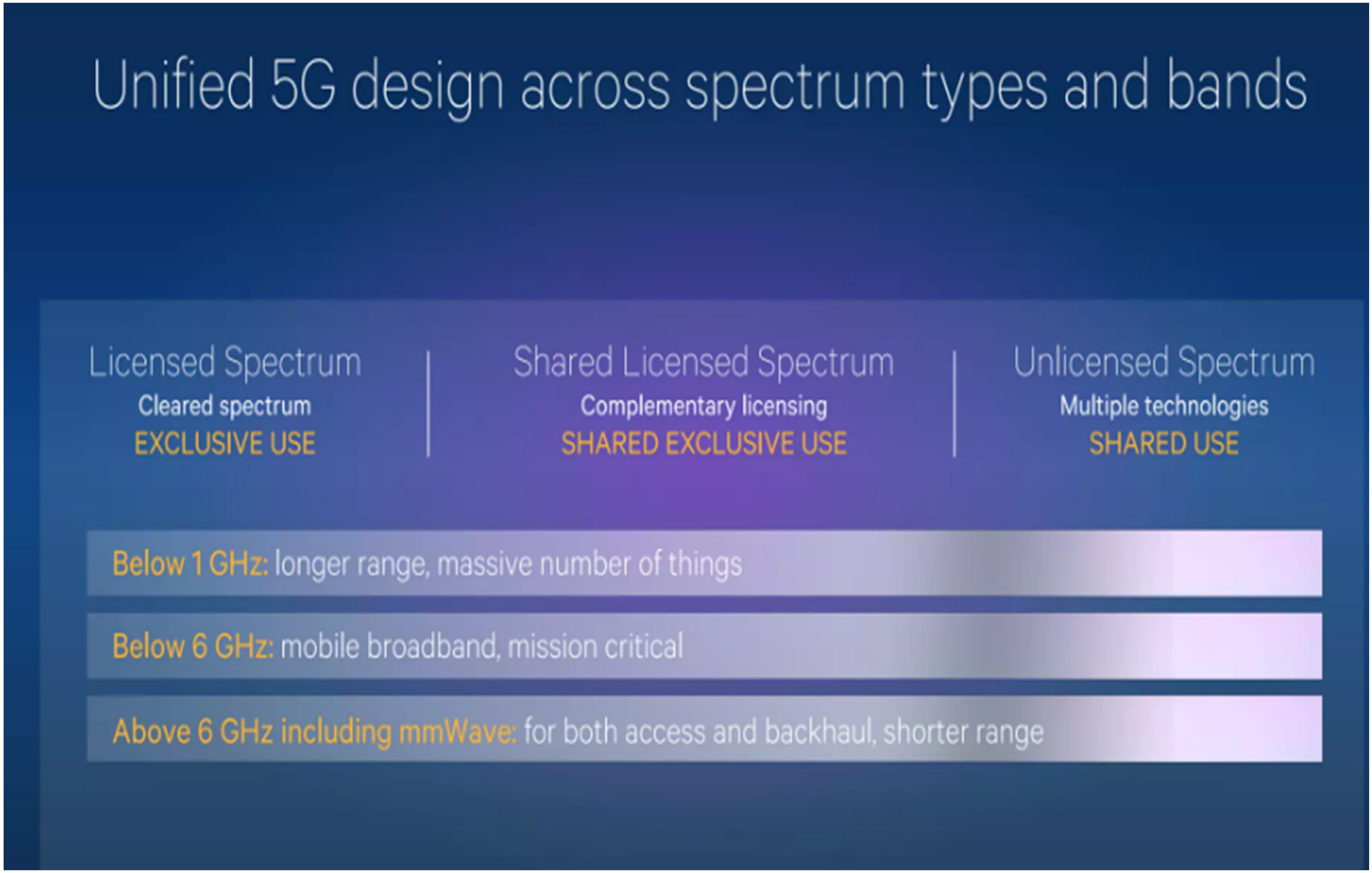
The 5G New Radio will provide a significant enhancements in areas like flexibility, scalability and efficiency, both in terms of power usage and spectrum.

5G Architecture



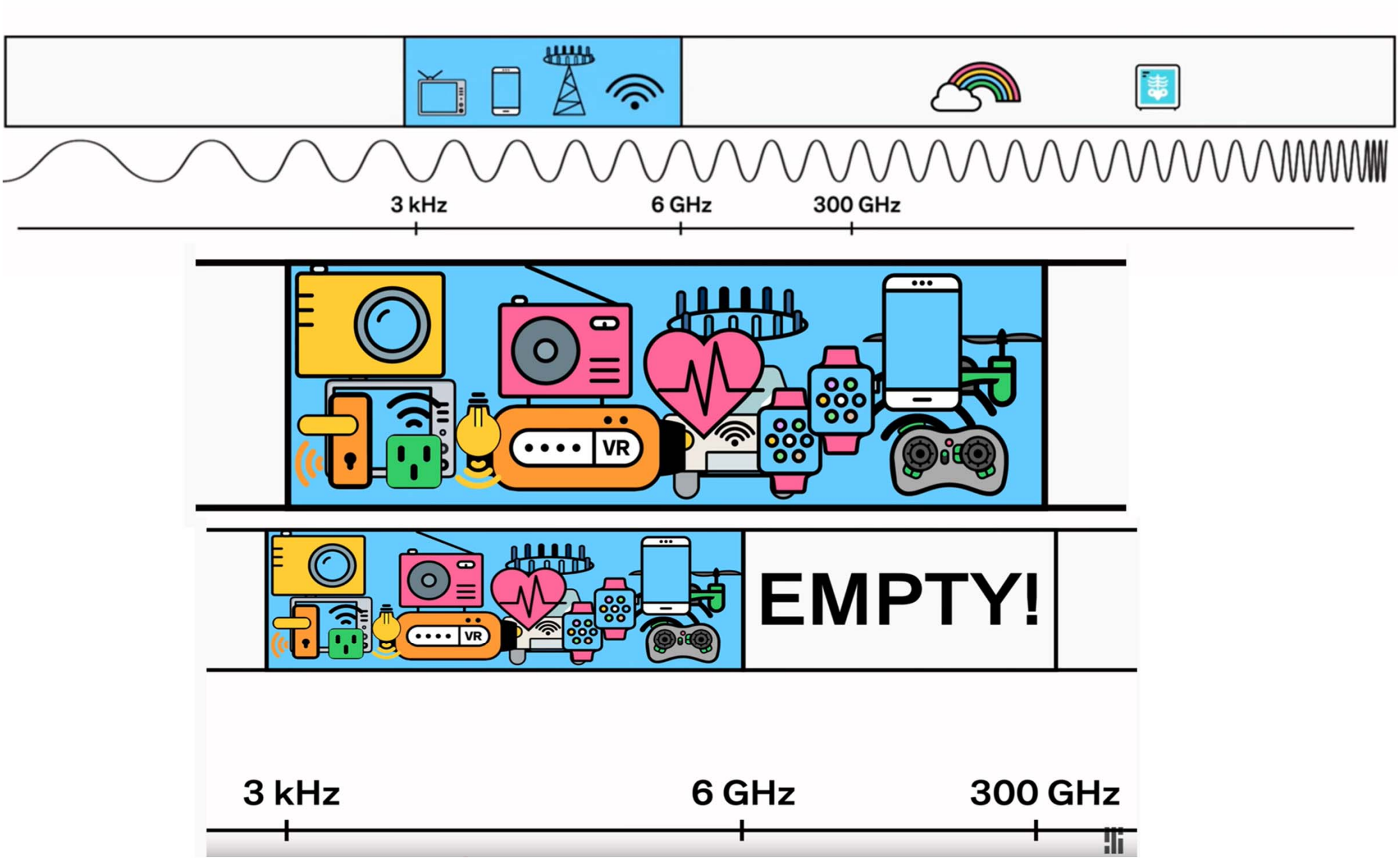

User-centric connectivity
Achieving truly edgeless connectivity with 5G
Multi-hop to extend coverage
Device-to-device discovery and communications
Integrated access and backhaul, relays


And multiple enablers for uniform user experiences and more capacity
Context and service awareness
Full Self-Configuration
Truly unplanned deployments
Hyper dense deployments
Backhaul
Interference Coordination
Beam forming
Coordinated Spatial Techniques
Advanced Receivers
Massive Spatial Processing

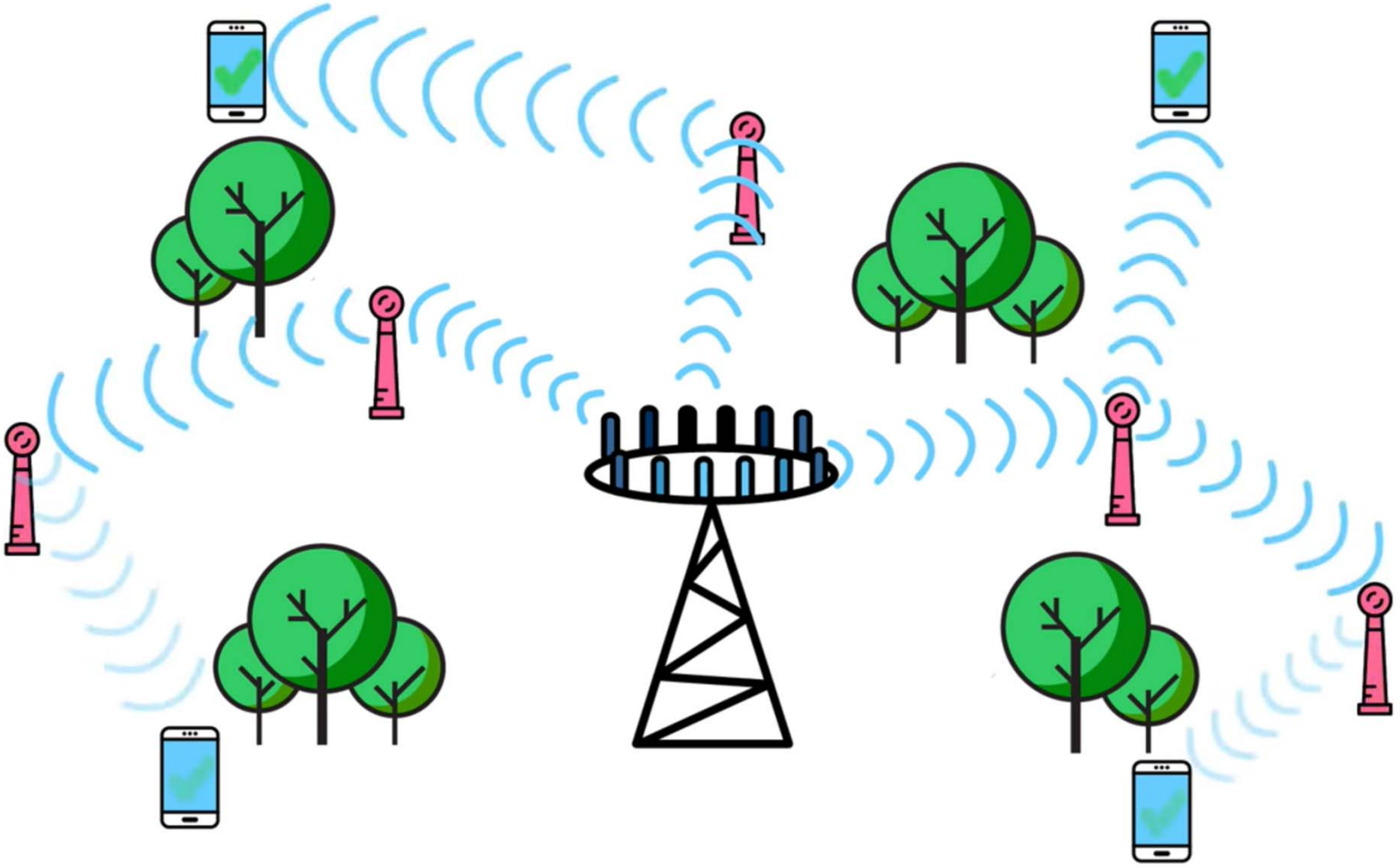

Unified 5G design across spectrum types and bands
Licensed Spectrum
Cleared spectrum
EXCLUSIVE USE
Shared Licensed Spectrum
Complementary licensing
SHARED EXCLUSIVE USE
Unlicensed Spectrum
Multiple technologies
SHARED USE
Below 1 GHz: longer range, massive number of things
Below 6 GHz: mobile broadband, mission critical
Above 6 GHz including mmWave: for both access and backhaul, shorter range

5G Architecture

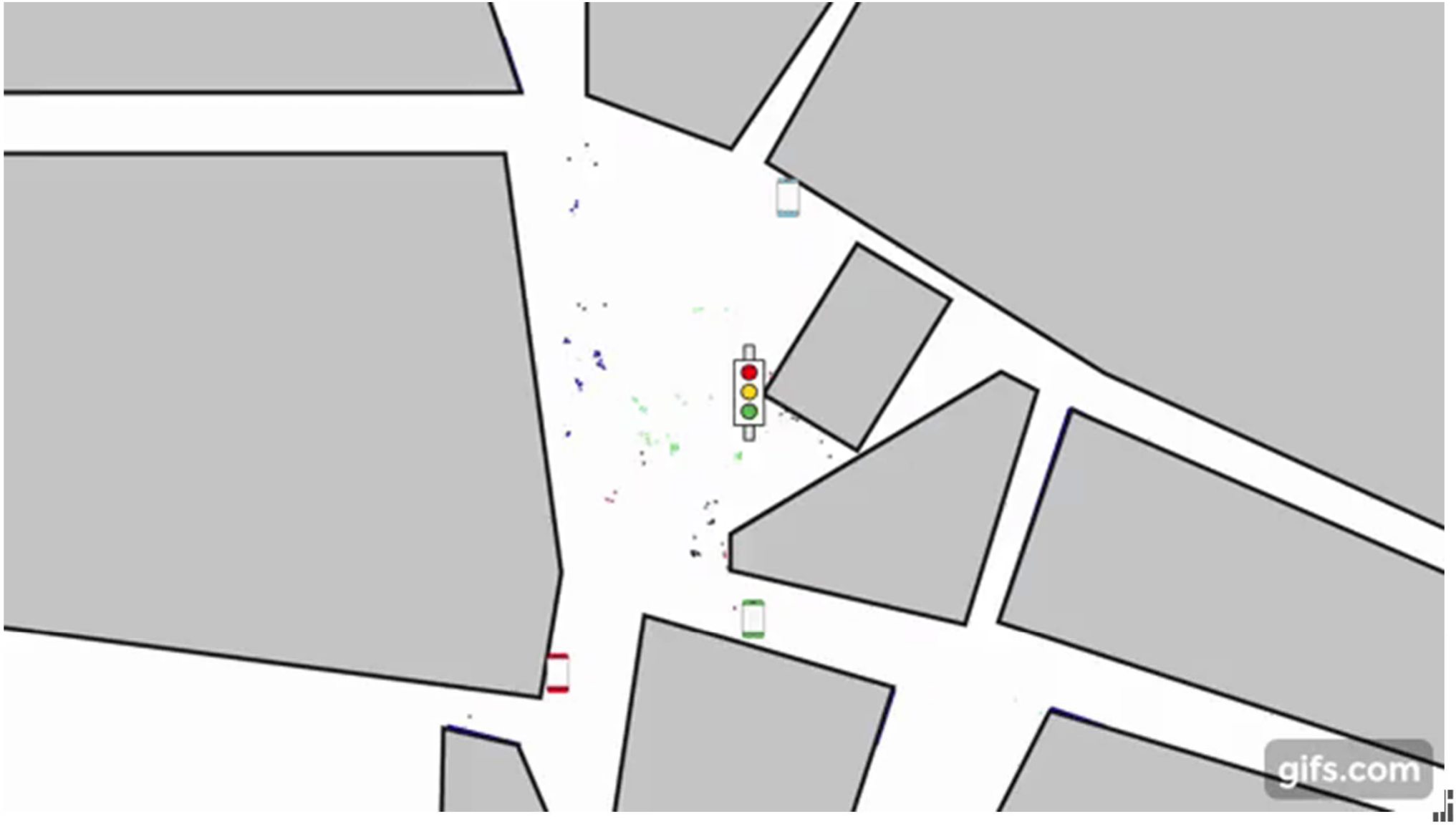
5G Architecture – Millimeter Waves



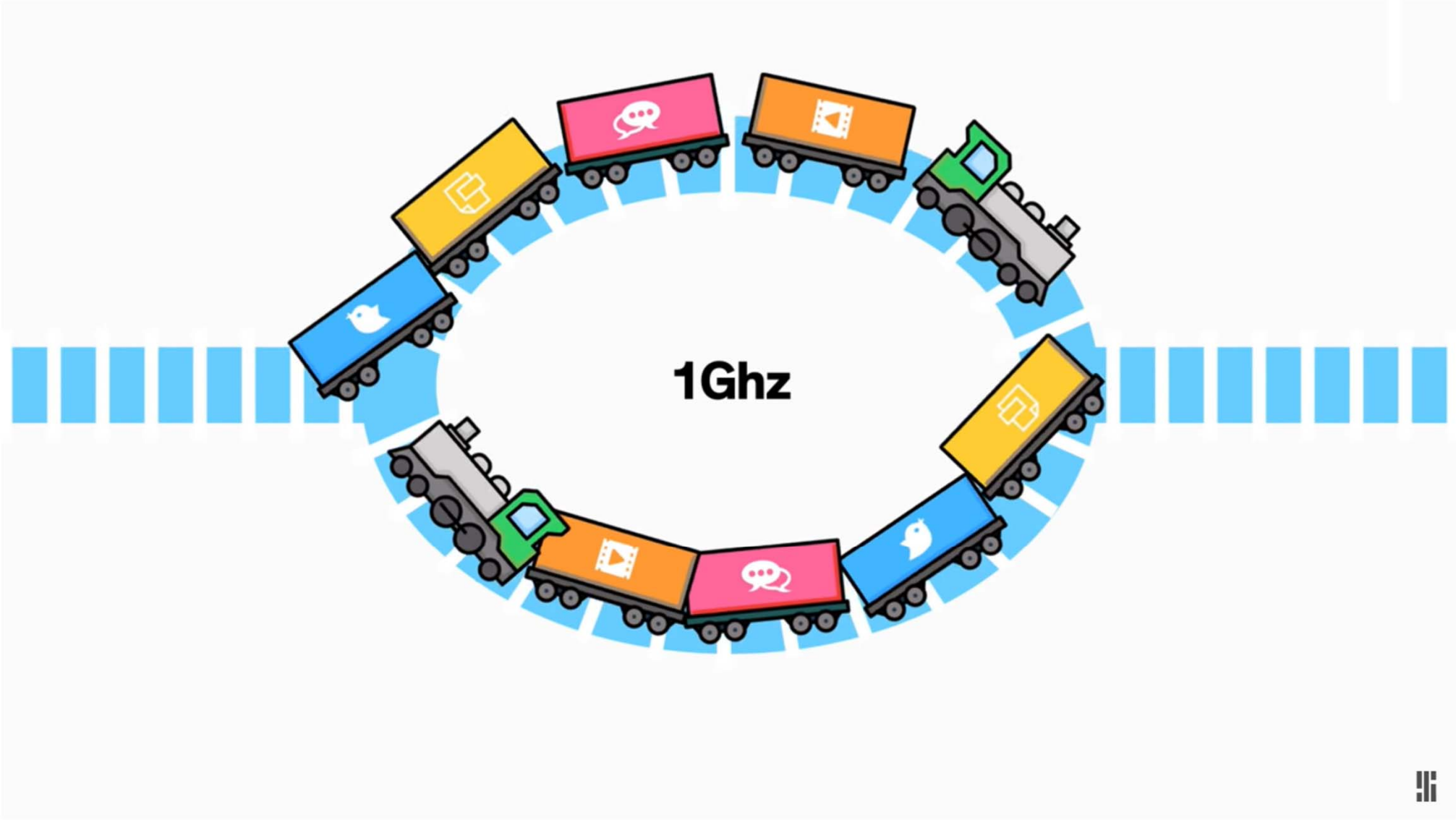
5G Architecture – Small Cells



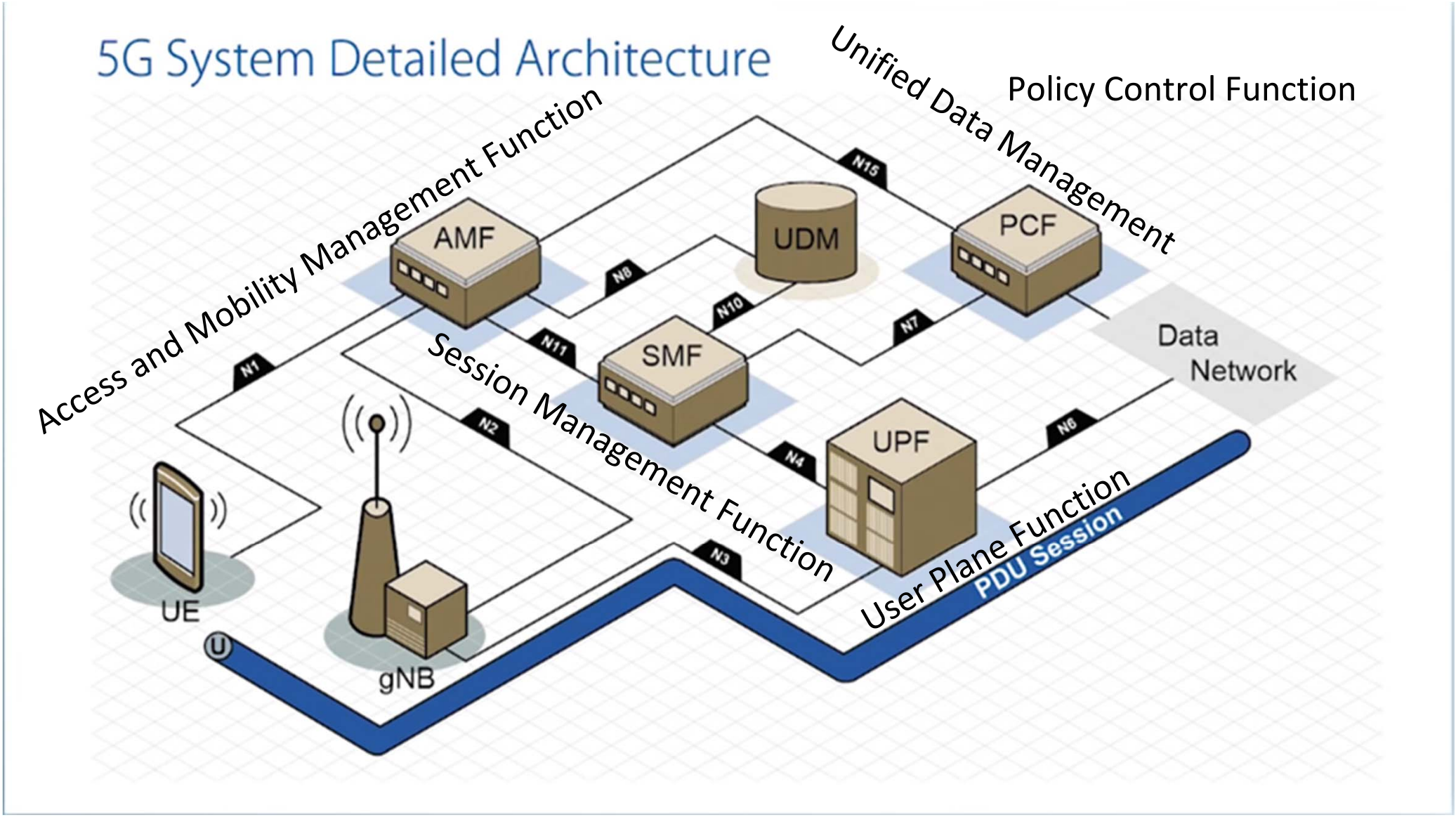
5G Architecture – Beamforming



5G Architecture – Fullduplex

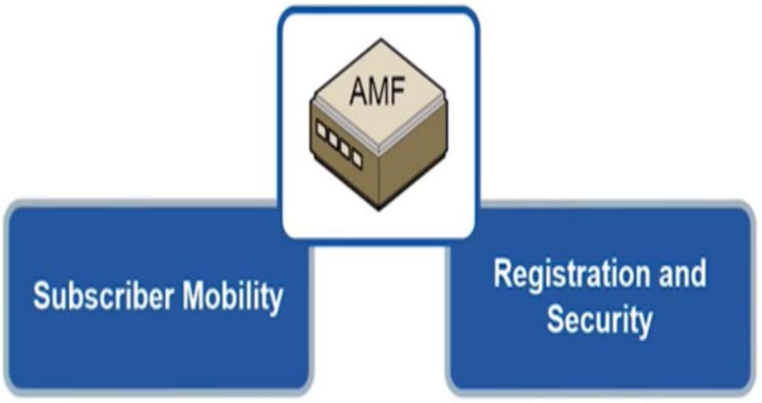


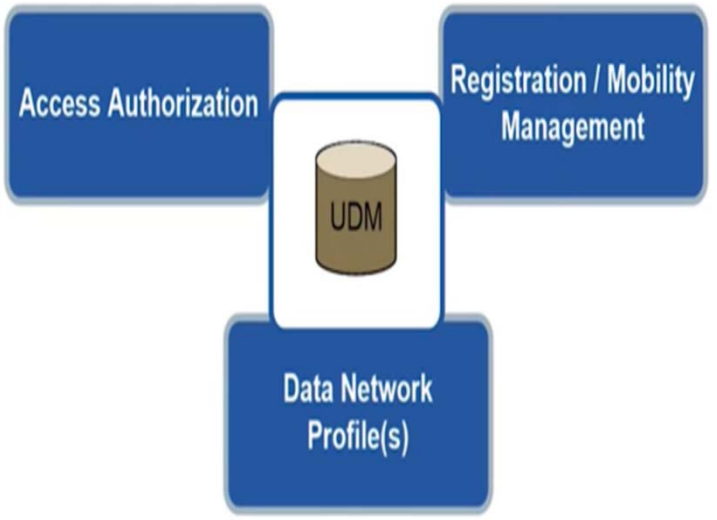
5G Architecture

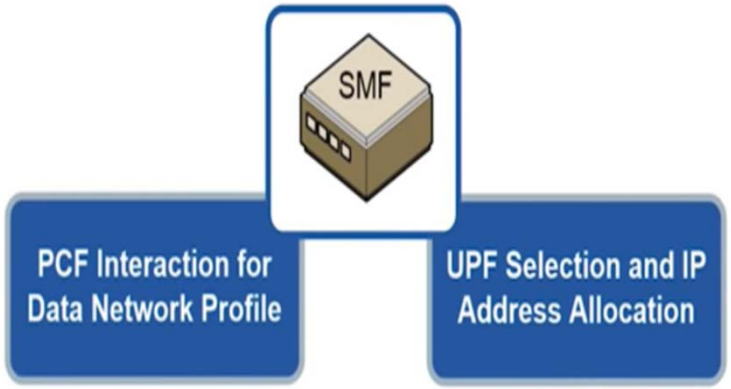


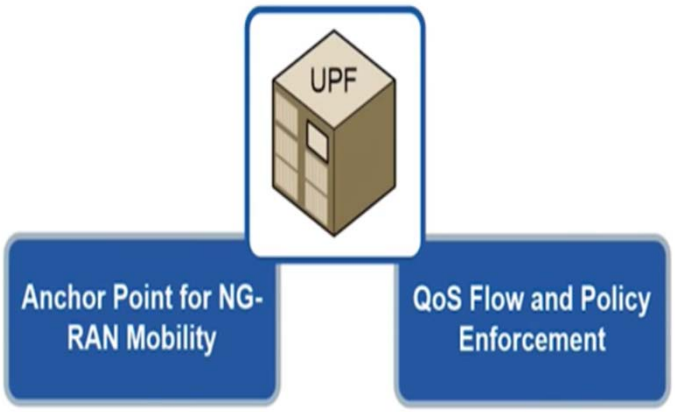
Mpirical

5G Architecture





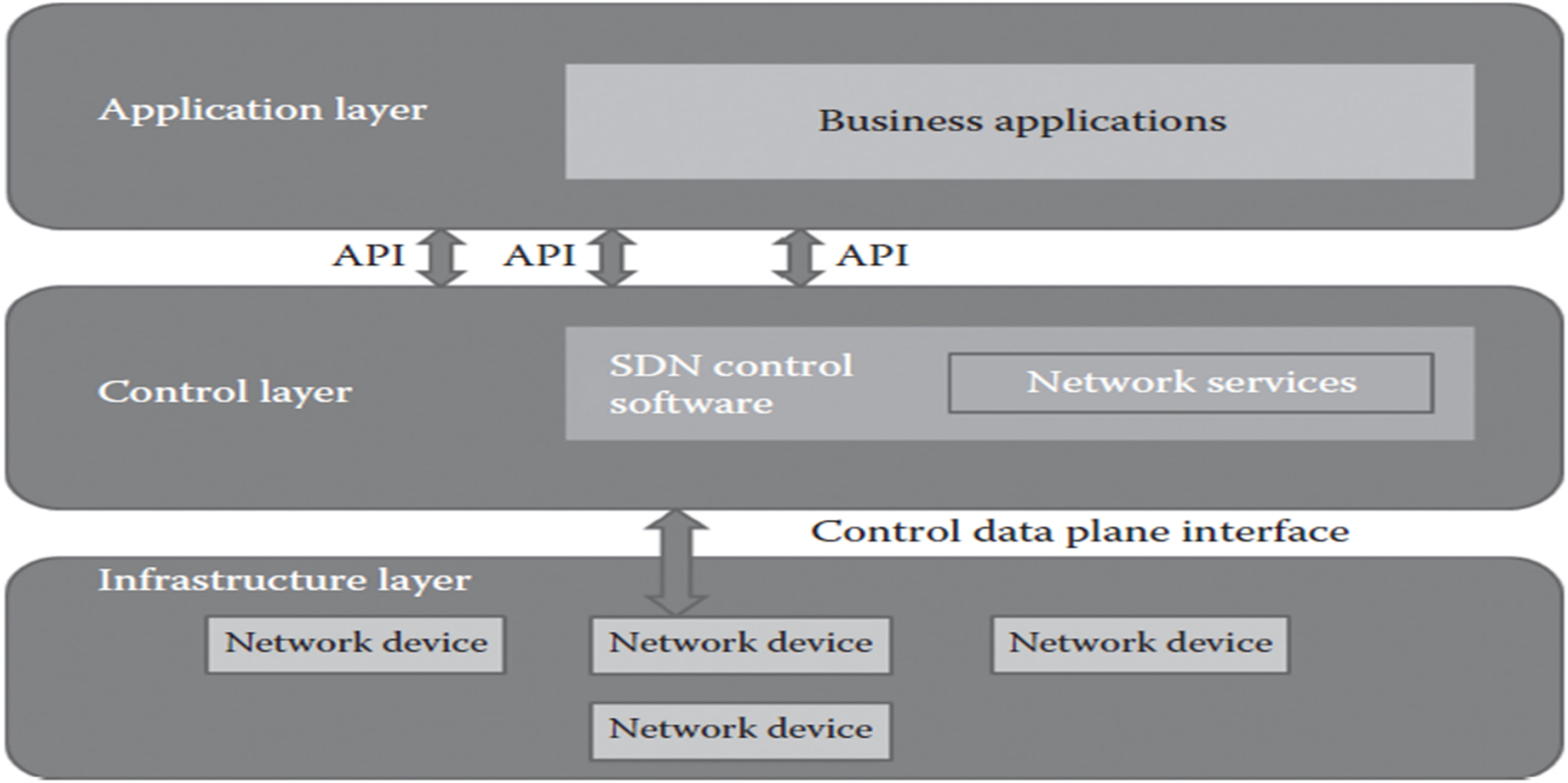




5G Technology

It enables all the above through

SOFTWARE DEFINED NETWORKS (SDN):

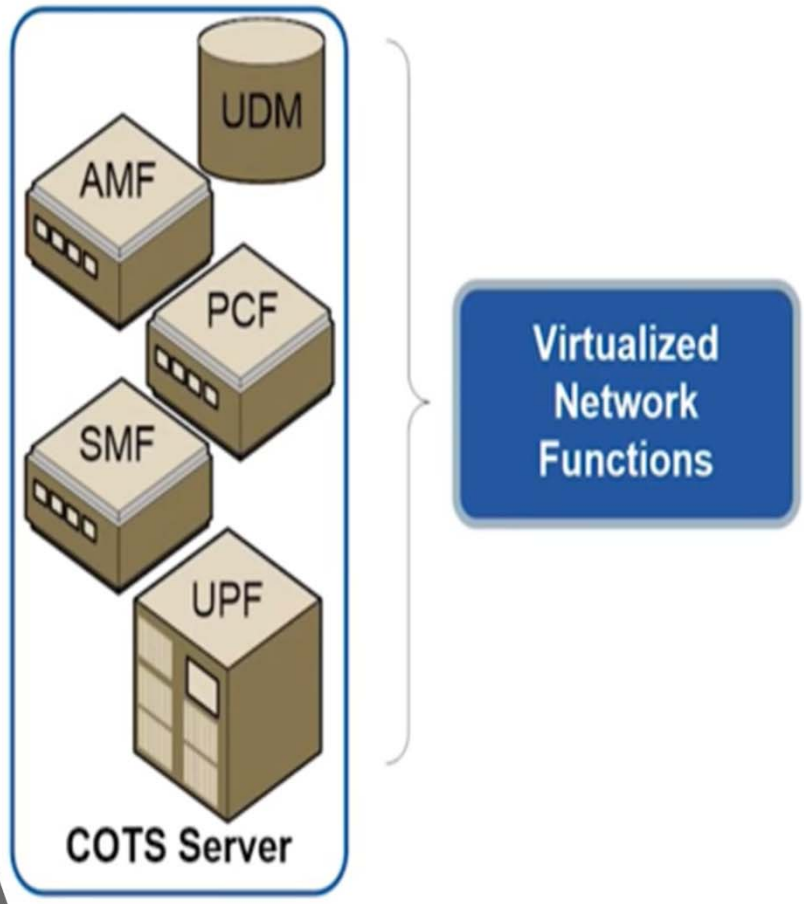


5G Technology

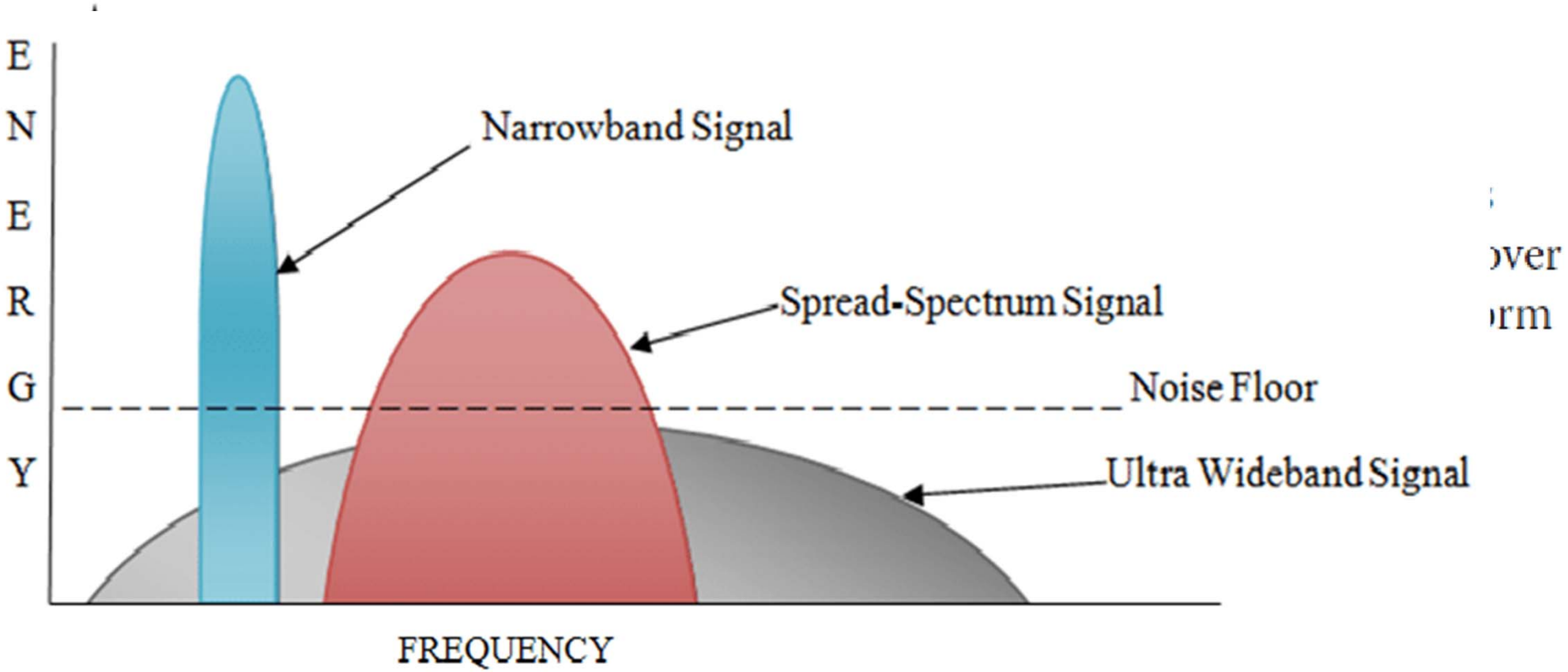
It enables all the above through SDN & NFV

NETWORK FUNCTION VIRTUALIZATION (NFV):

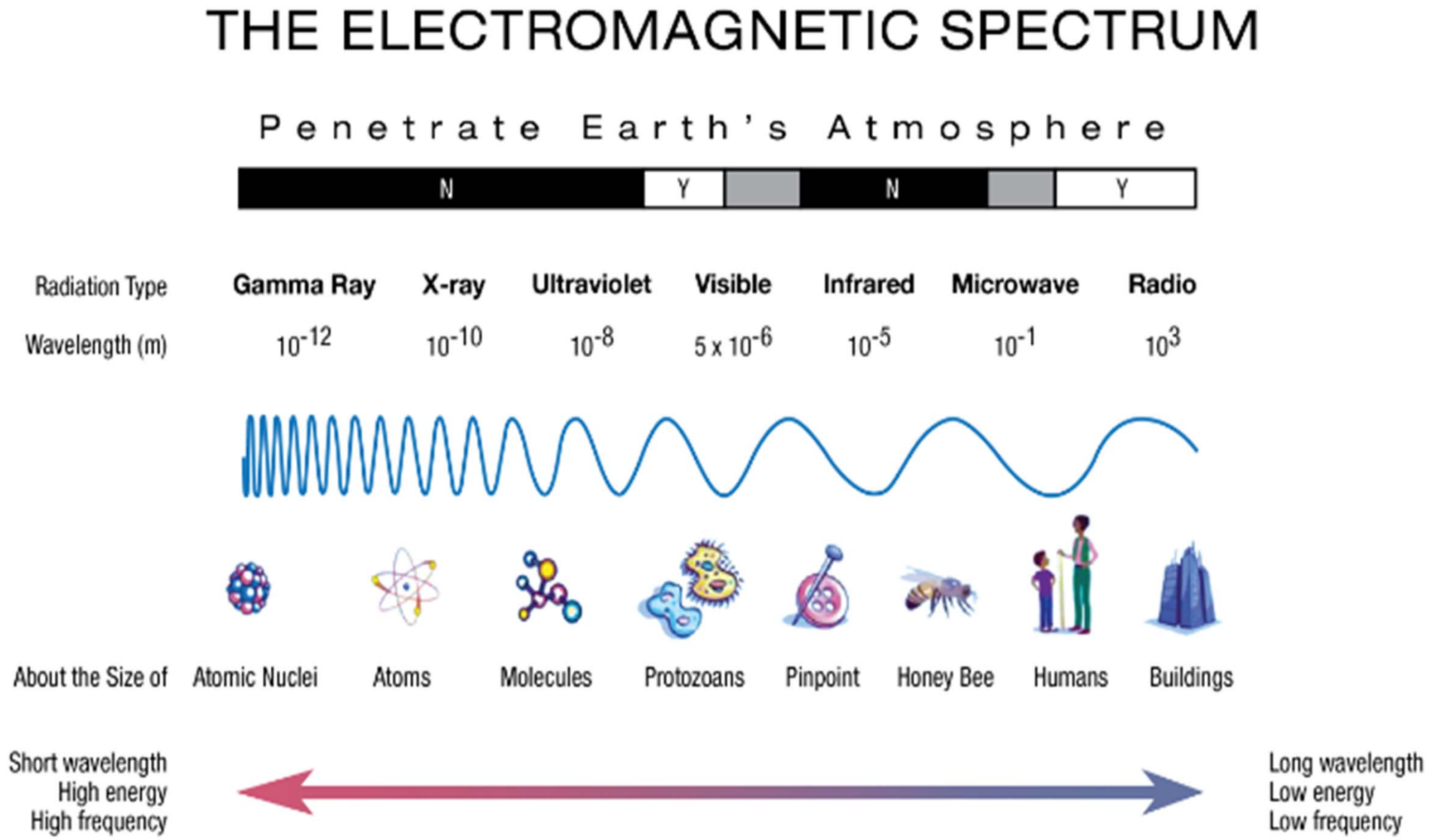
- Services that are implemented in a machine that has multiple or compartmentalized OS(s)
- Services that are implemented within a single hypervisor
- Services that are implemented as distributed or clustered as composites
- Services that are implemented on bare metal machines
- Services that are implemented in Linux virtual containers



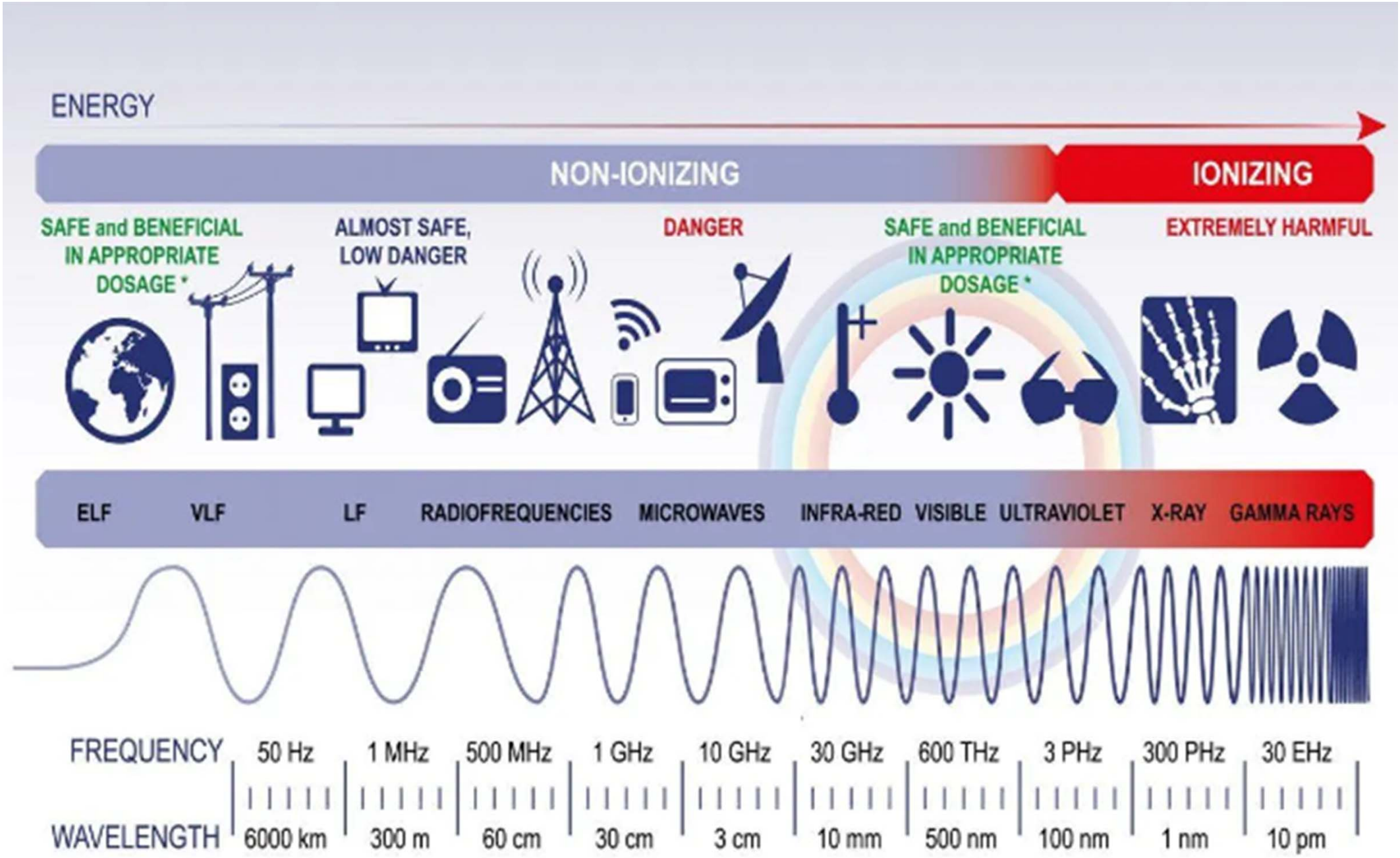
Ultra Wide Band



MBOA Phy

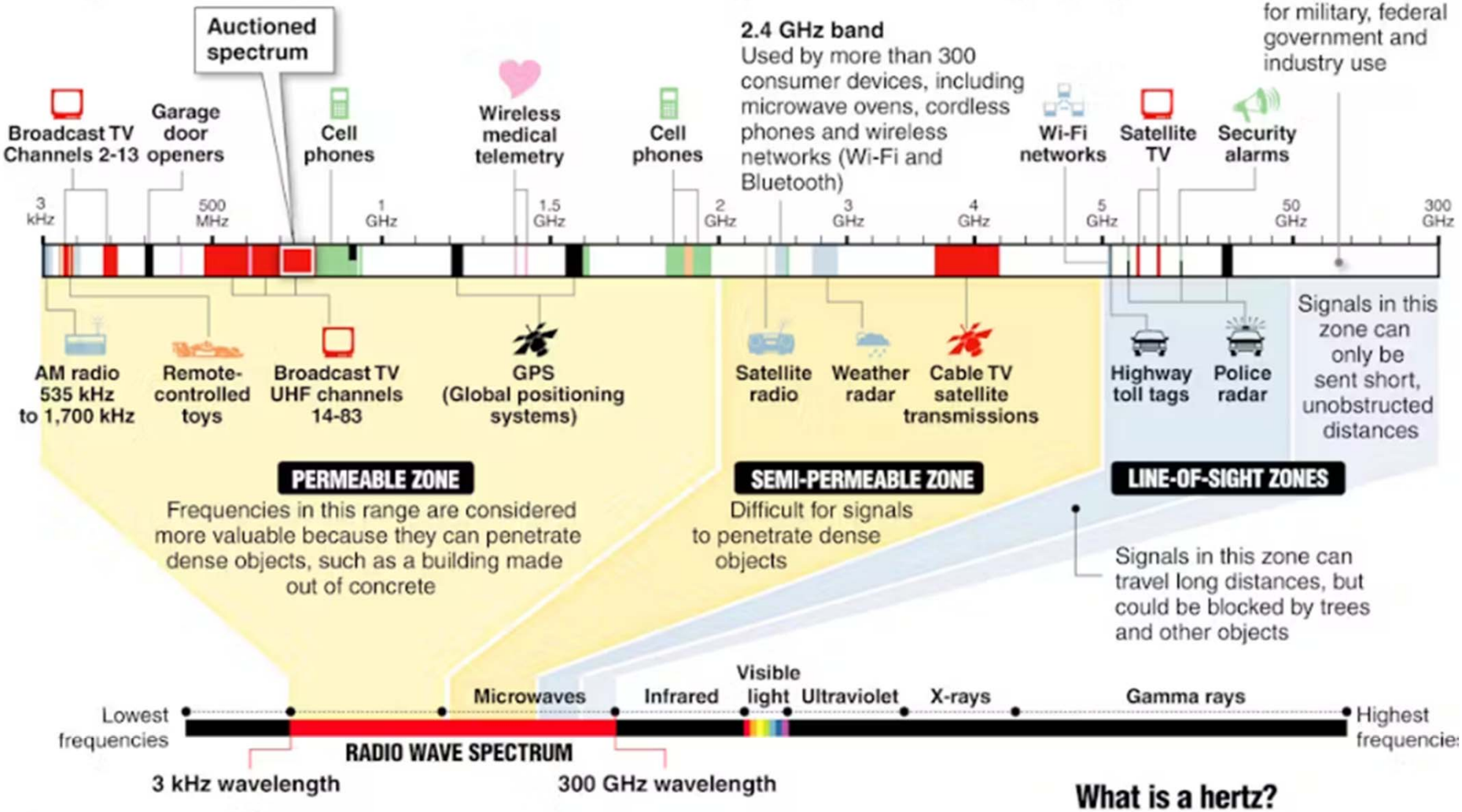


The Electromagnetic Spectrum. Image Credit: NASA


ENERGY
NON-IONIZING
IONIZING
SAFE and BENEFICIAL IN APPROPRIATE DOSAGE *
ALMOST SAFE, LOW DANGER
DANGER
SAFE and BENEFICIAL IN APPROPRIATE DOSAGE *
EXTREMELY HARMFUL
ELF
VLF
LF
RADIOFREQUENCIES
MICROWAVES
INFRA-RED
VISIBLE
ULTRAVIOLET
X-RAY
GAMMA RAYS
FREQUENCY
50 Hz
1 MHz
500 MHz
1 GHz
10 GHz
30 GHz
600 THz
3 PHz
300 PHz
30 EHz
WAVELENGTH
6000 km
300 m
60 cm
30 cm
3 cm
10 mm
500 nm
100 nm
1 nm
10 pm

Inside the radio wave spectrum

Almost every wireless technology – from cell phones to garage door openers – uses radio waves to communicate. Some services, such as TV and radio broadcasts, have exclusive use of their frequency within a geographic area. But many devices share frequencies, which can cause interference. Examples of radio waves used by everyday devices:



The electromagnetic spectrum

Radio waves occupy part of the electromagnetic spectrum, a range of electric and magnetic waves of different lengths that travel at the speed of light; other parts of the spectrum include visible light and x-rays; the shortest wavelengths have the highest frequency, measured in hertz

What is a hertz?

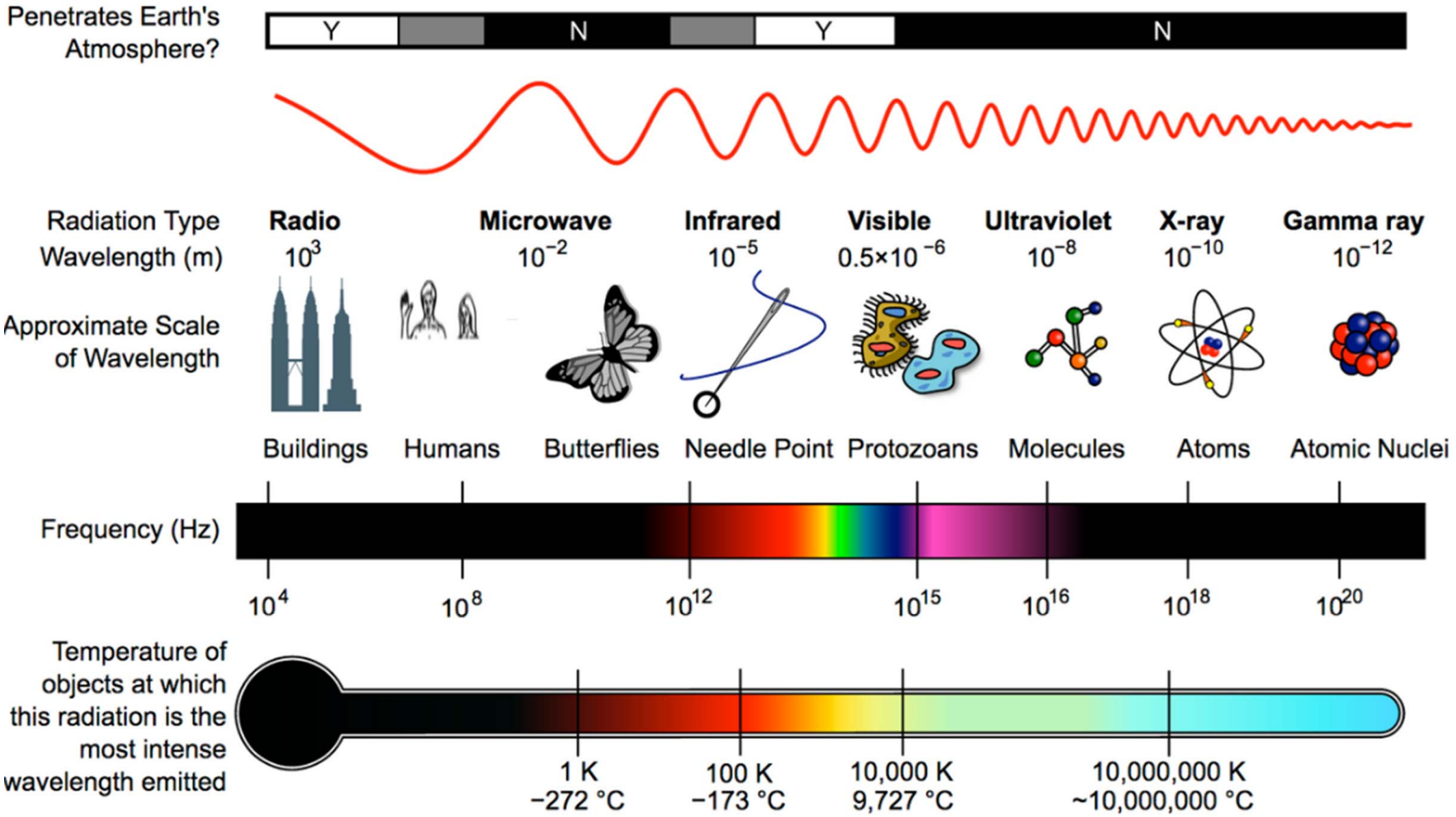
One hertz is one cycle per second. For radio waves, a cycle is the distance from wave crest to crest

1 kilohertz (kHz) = 1,000 hertz

1 megahertz (MHz) = 1 million hertz

1 gigahertz (GHz) = 1 billion hertz

Source: New America Foundation, MCT, Howstuffworks.com


Penetrates Earth's Atmosphere?
Y
N
Y
N
Radiation Type
Wavelength (m)
Approximate Scale of Wavelength
Radio
10^{3}
Microwave
10^{-2}
Infrared
10^{-5}
Visible
0.5×10^{-6}
Ultraviolet
10^{-8}
X-ray
10^{-10}
Gamma ray
10^{-12}
Buildings
Humans
Butterflies
Needle Point
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
10^{4}
10^{8}
10^{12}
10^{15}
10^{16}
10^{18}
10^{20}
Temperature of objects at which this radiation is the most intense wavelength emitted
1 K
−272 °C
100 K
−173 °C
10,000 K
9,727 °C
10,000,000 K
~10,000,000 °C

Low Power Wide Area Network (LPWAN)

- LPWAN has two network topologies:
  - Direct device connectivity (base station)
  - Indirect device connectivity through an LPWAN gateway

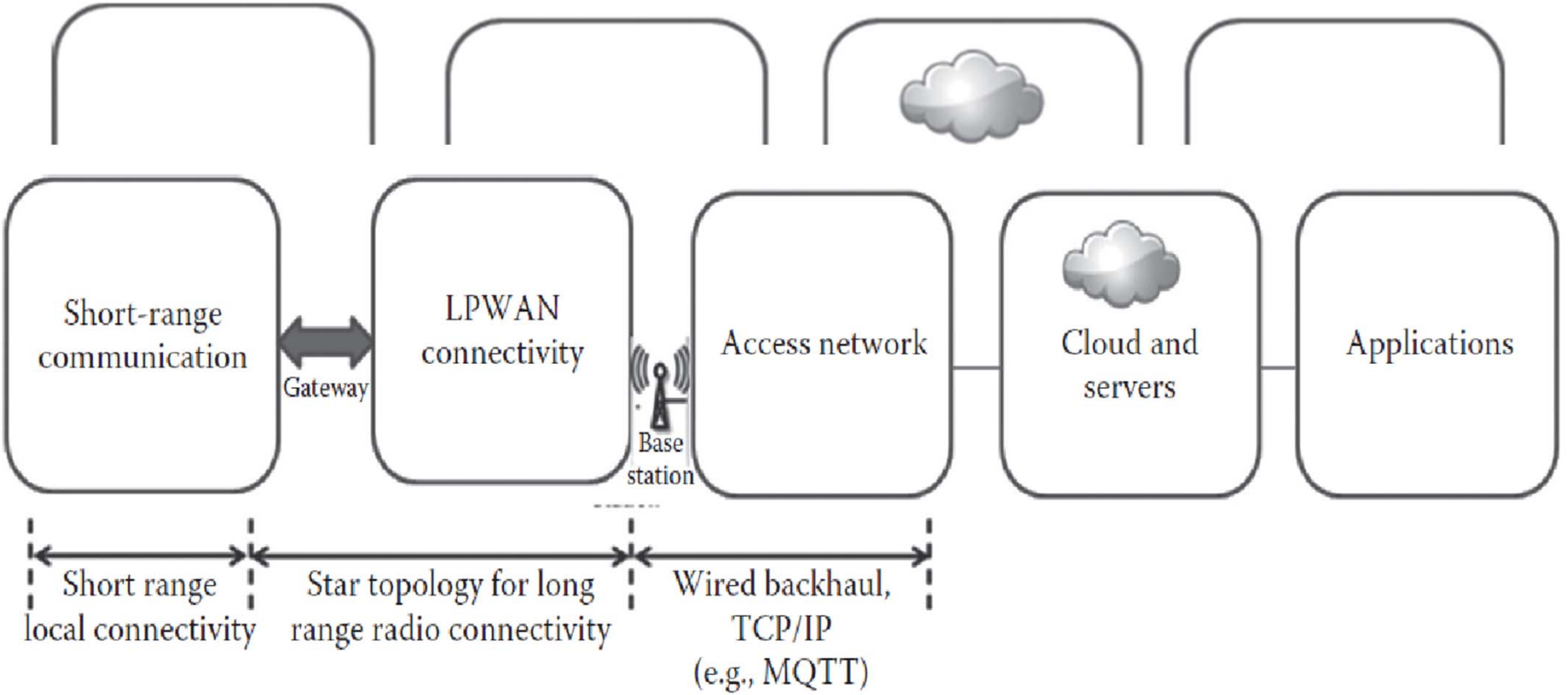
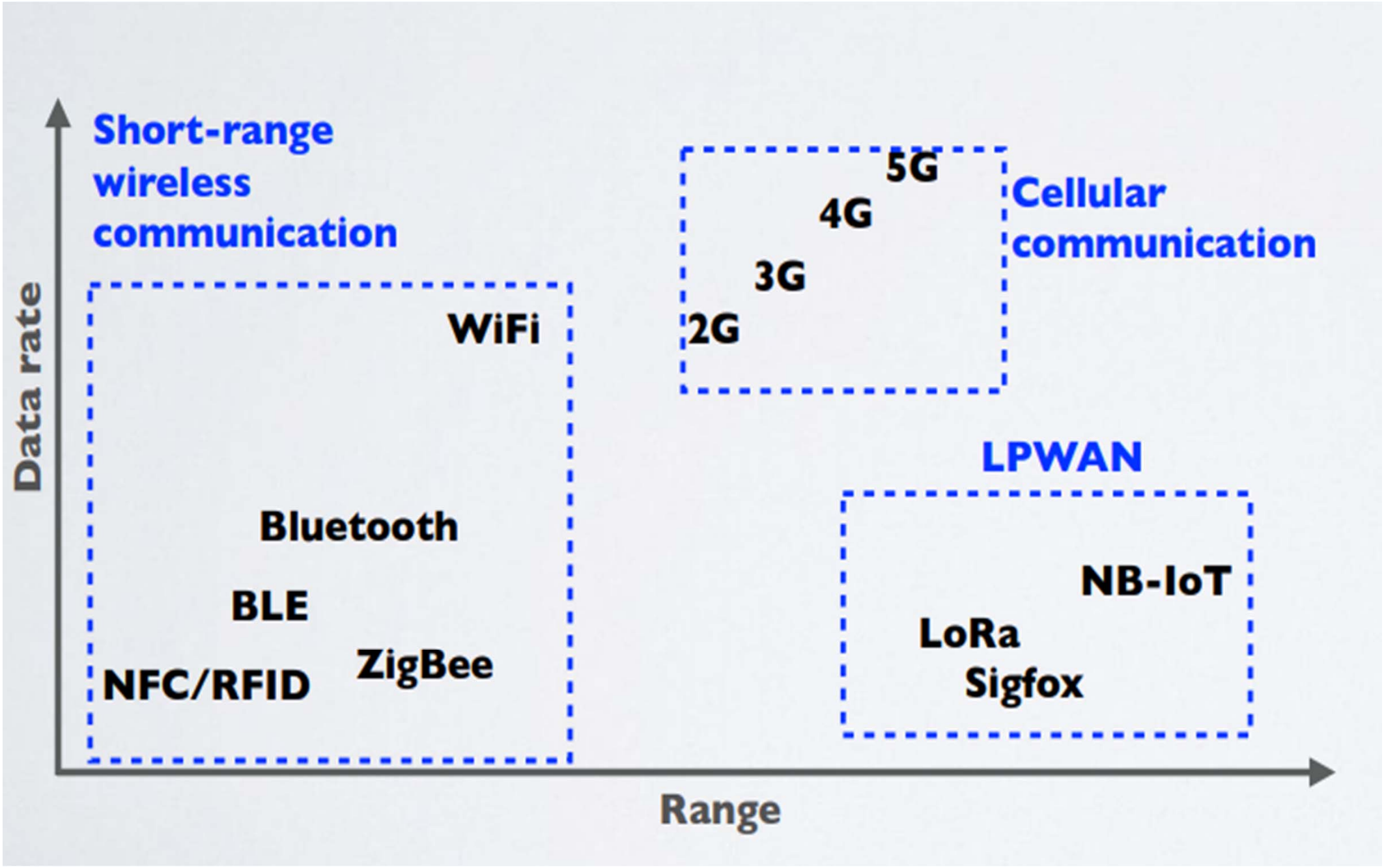


Figure 2.13 Indirect device connectivity through an LPWAN gateway.

LPWAN


Short-range
wireless
communication
WiFi
Bluetooth
BLE
ZigBee
NFC/RFID
5G
4G
3G
2G
Cellular
communication
LPWAN
NB-IoT
LoRa
Sigfox
Data rate
Range

Wireless comparision

Wireless Technology	Wireless Communication	Range (m)	Tx power (mW)
Bluetooth	Short range	~10	~2.5
WIFI	Short range	~50	~80
3G / 4G	Cellular	~5000	~500
LoRa*	LPWAN	2000-5000 (urban area) 5000-15000 (rural area) > 15000 (direct line of sight)	~20

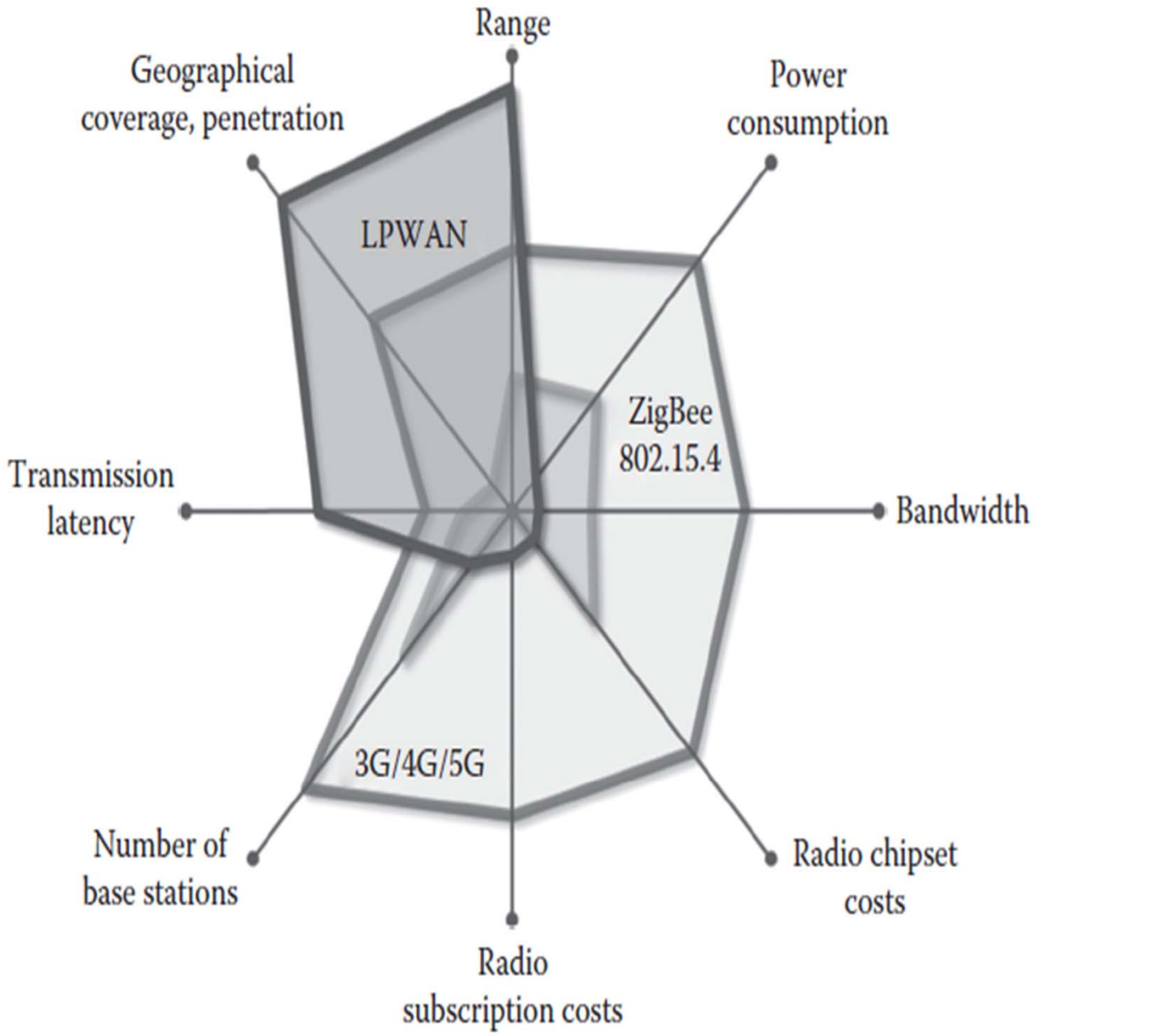
* Data packages are very small

src: mobilefish.com

LPWAN

Why Choose LPWAN?

- Capacity
- Quality of service
- Range
- Reliability
- Battery life
- Security
- Cost
- Proprietary versus standard



Requirements of LPWAN technologies.

Sigfox

Sigfox does not support bidirectional Networks

15 bytes of traffic at a time with an average of only 10 messages per day

868 or 915 MHz frequency bands

Binary phase shift keying (BPSK)

LoRa

- By SemTech
- LoRa is an acronym for Long Range and it is a wireless technology where a low powered sender transmit small data packages (0.3 kbps to 5.5 kbps) to a receiver over a long distance
- A LoRa end node consists of 2 parts:
  - A radio module with antenna.
  - A microprocessor to process for example the sensor data.
  - Battery powered
- A LoRa Device+sensor = Mote

LoRa

LoRa end node(mote) / gateway consists of 2 parts:

- A radio module with antenna
- A microprocessor to process the data

Multiple gateways can receive data from the same end node

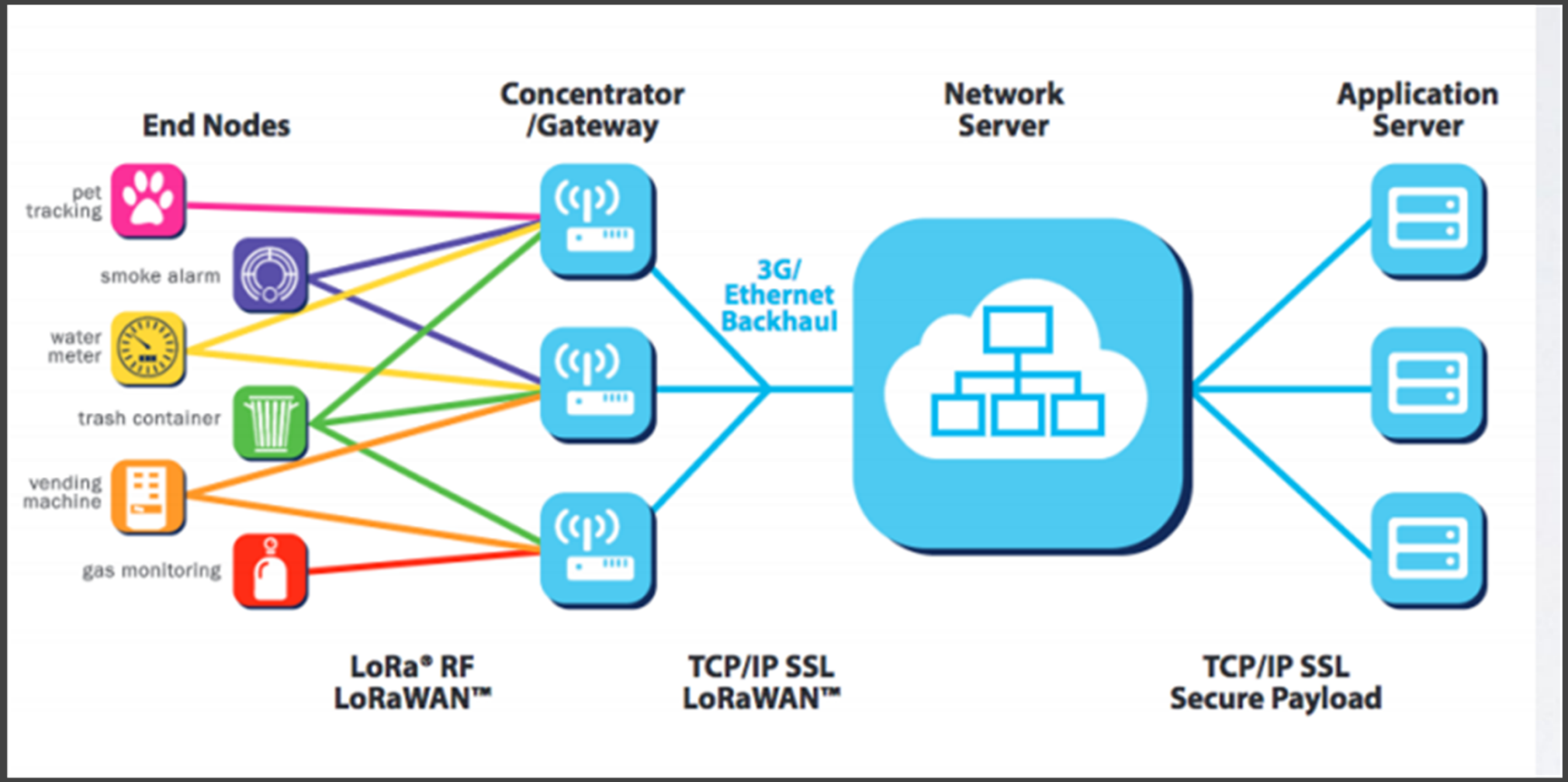
bi-directional communication, multicast addressing groups to make efficient use of spectrum during tasks such as Firmware Over-The-Air (FOTA) upgrades

Chirp Spread Spectrum Modulation - is a spread spectrum technique that uses wideband linear frequency modulated chirp pulses to encode information

LoRa Range

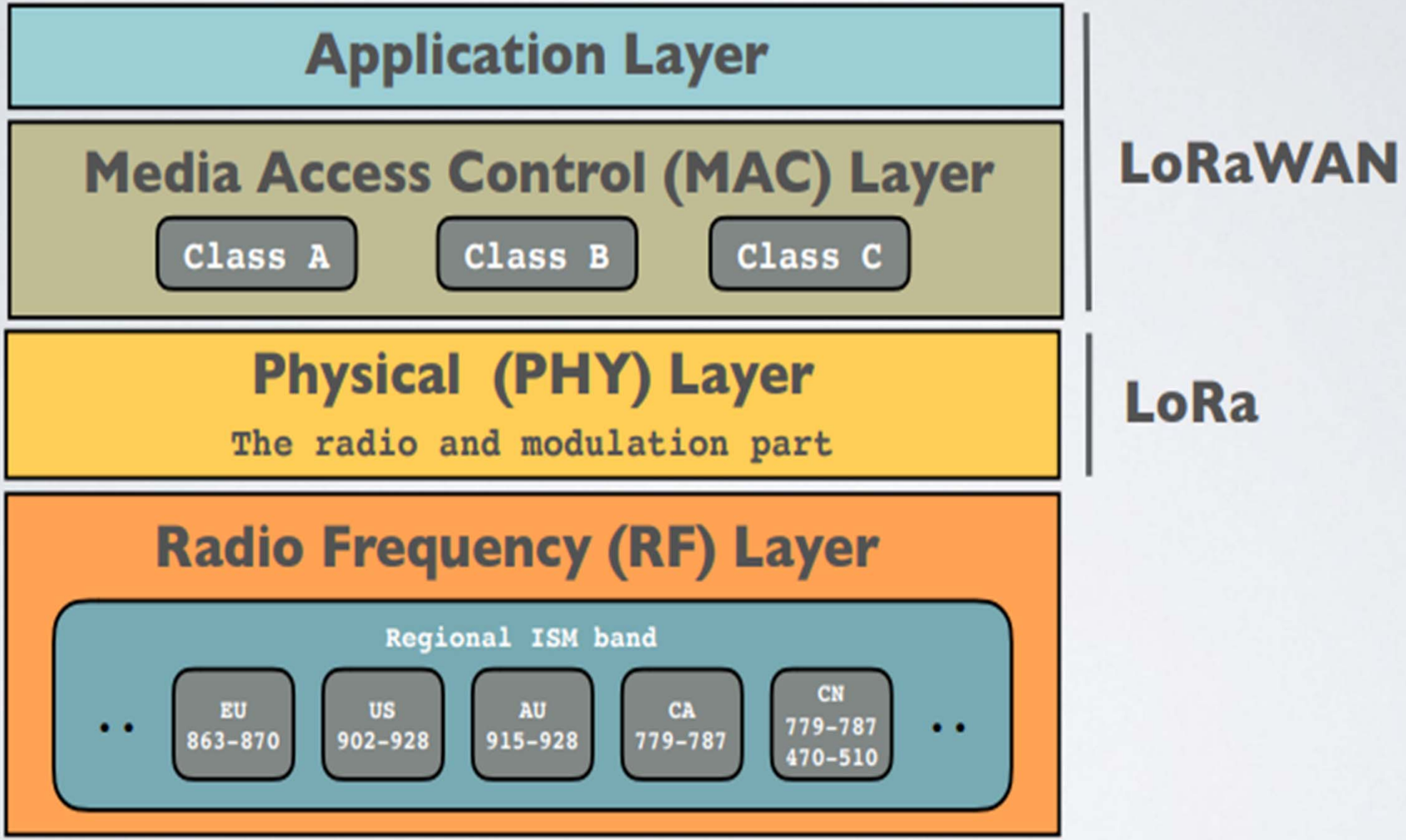
- The range between LoRa sender and receiver depends on the environment the equipment operates in. Indoor coverage largely depends on the type of building material used.

Environment	Range (km)
Urban areas (towns & cities)	2-5
Rural areas (countrysides)	5-15
Direct Line Of Sight	>15


End Nodes
Concentrator /Gateway
Network Server
Application Server
pet tracking
smoke alarm
water meter
trash container
vending machine
gas monitoring
3G/ Ethernet Backhaul
LoRa® RF LoRaWAN™
TCP/IP SSL LoRaWAN™
TCP/IP SSL Secure Payload

LoRa WAN

LORA PROTOCOL STACK



CLASS A (ALL)

- Class A - Lowest power, bi-directional end-devices
- The default class which must be supported by all LoRaWAN end-devices
- Class A communication is always initiated by the end-device and is fully asynchronous.
- Each uplink transmission can be sent at any time and is followed by two short downlink windows,

CLASS - B (Beacon)

- Class B – Bi-directional end-devices with deterministic downlink latency
- In addition to the class A initiated receive windows, class B devices are synchronised to the network using periodic beacons, and open downlink ‘ping slots’ at scheduled times.
- This provides the network the ability to send downlink communications with a deterministic latency,

CLASS – C (Continous)

- Class C – Lowest latency, bi-directional end-devices
- In addition to the class A structure of uplink followed by two downlink windows, class C further reduces latency on the downlink by keeping the receiver of the end-device open at all times that the device is not transmitting (half duplex)
- Battery powered devices, temporary mode switching between classes A & C is possible, and is useful for intermittent tasks such as firmware over-the-air updates.

- The **frequency** band for **LoRa** Technology in **India** is 865 MHz to 867 MHz

Govt Notification:

- G.S.R.36 (E).- In exercise of the powers conferred by sections 4 and 7 of the Indian Telegraph Act, 1885 (13 of 1885) and sections 4 and 10 of the Indian Wireless Telegraphy Act, 1933 (17 of 1933), the Central Government hereby makes the following rules, to amend the “Use of low power Equipment in the frequency band 865 – 867 MHz for (RFID) Radio Frequency Identification Devices (Exemption from Licensing Requirement) Rules, 2005.”

Region	LoRa Frequency Band	LoRa Channel Frequency
EU	863 to 870 MHz	868.10 Mhz (used by Gateway to listen) 868.30 MHz (used by Gateway to listen) 868.50 MHz (used by Gateway to listen) 864.10 MHz (used by End device to transmit Join Request) 864.30 MHz (used by End device to transmit Join Request) 864.50 MHz (used by End device to transmit Join Request) 868.10 MHz (used by End device to transmit Join Request) 868.30 MHz (used by End device to transmit Join Request) 868.50 MHz (used by End device to transmit Join Request)
US	902 to 928 MHz	902.3 MHz to 914.9 MHz spaced at 200KHz (Upstream-64 channels) 903 MHz to 914.2 MHz spaced at 1.6 MHz apart (Upstream- 8 channels) 923.3 MHz to 927.5 MHz spaced at 600KHz apart (Downstream- 8 channels)
China	779 to 787 MHz	779.5 MHz (Default channel) 779.7 MHz (Default channel) 779.9 MHz (Default channel) 779.5 MHz (Used by ED to transmit Join Request) 779.7 MHz (Used by ED to transmit Join Request) 779.9 MHz (Used by ED to transmit Join Request) 780.5 MHz (Used by ED to transmit Join Request) 780.7 MHz (Used by ED to transmit Join Request) 780.9 MHz (Used by ED to transmit Join Request)

Weightless

Weightless is an open LPWAN

Weightless-P

- Bidirectional communication
- Narrow band modulation
- 100 uW power consumption in an idle state

Weightless-N

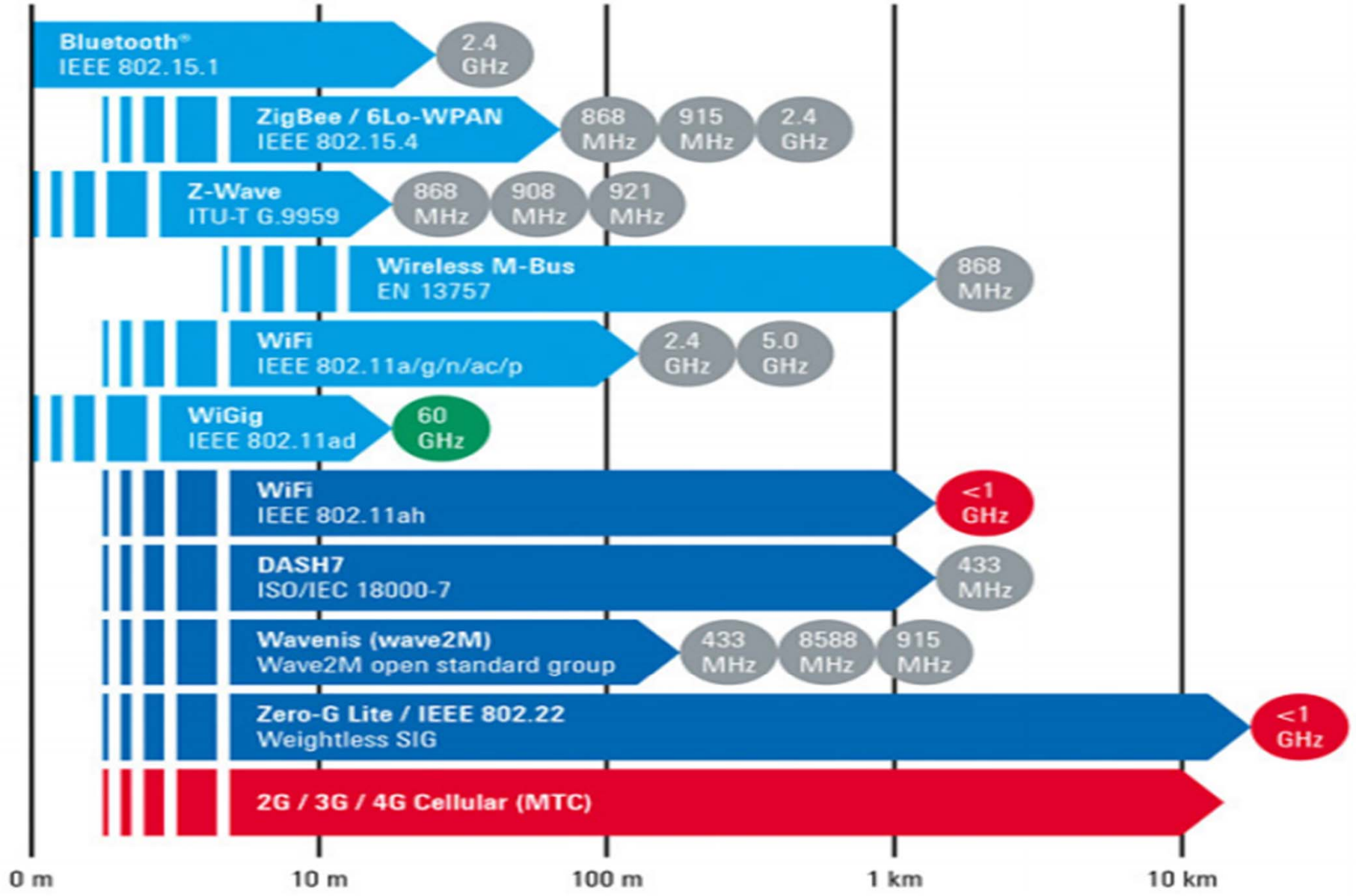
- One way communication
- star network
- ultra narrow band
- Sub-GHz spectrum
- differential binary phase shift keying
- 128-bit AES algorithm

Weightless

Weightless-W

- Runs in the unused TV spectrum
- 1 Kbit/s to 10 Mbit/s
- Multicast
- Ultra secure 128-bit encryption and authentication model
- Range is about 5 km in indoor

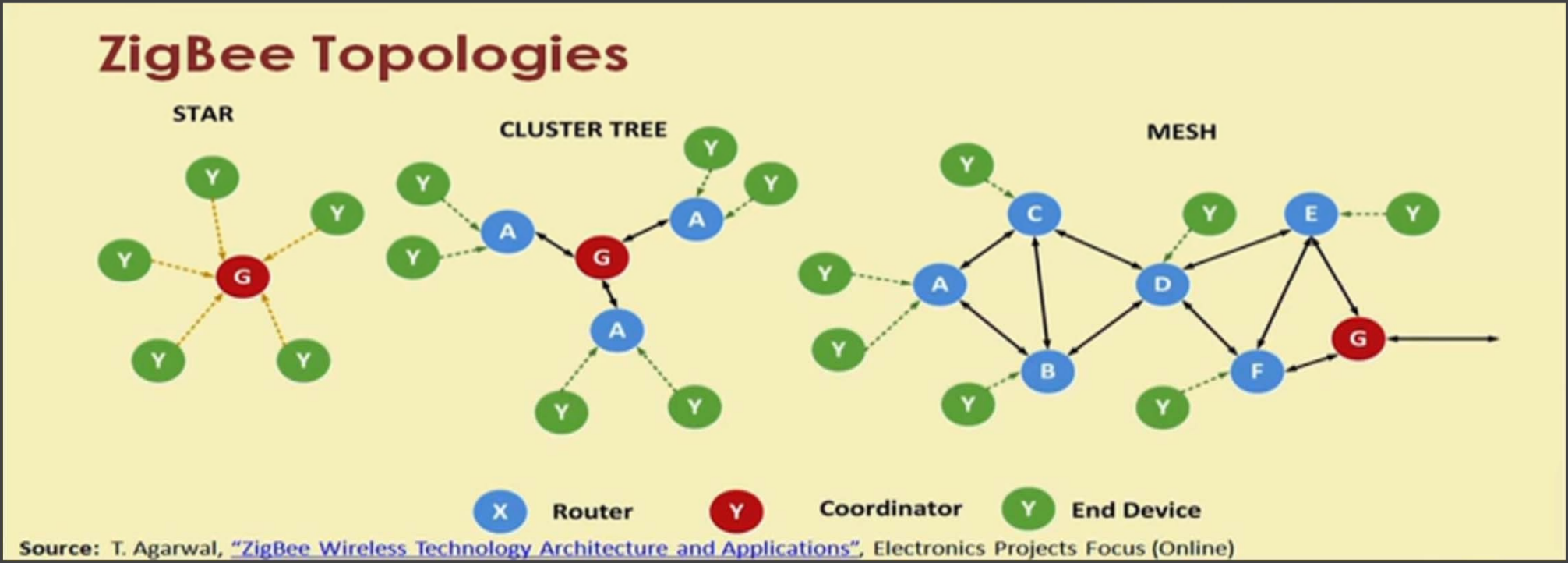
Frequency bands by different technologies



Src: https://www.raviyp.com/868-mhz-frequency-is-not-license-free-in-india-lora-in-india/

- Most widely deployed enhancement of IEEE 802.15.4
- Operates at Layer 1, 2 of 802.15.4 (Physical & MAC)
- Uses Mesh Topology, therefore high reliability and Self-configuring and self-healing
- Uses AODV routing
- Components
  - **Zigbee Device Object**: Device management, Security & Policies
  - **Application Support Sub-layer**: Interfacing and control services, bridge between N/w & other layers

zigbee



Zigbee

- **Zigbee Coordinator:** One coordinator in each network, Trust center & repository
- **Zigbee Router**: Running applications, as well as relaying information between nodes
- **Zigbee End device**: Contains enough functionality to talk to parent node, and it cannot relay data from other devices, goes into sleep mode to save battery

Specifications & Features

- Interoperable with other ZigBee-compliant devices
- Supports binding and multicasting for easy integration into a home automation platform
- Out-of-the-box RF communications, no configuration needed
- 2.4GHz for worldwide deployment
- Firmware upgrades via UART, SPI or over the air
- Data Rate RF: 250Kbps, serial up to 1Mbps
- Indoor/urban range: 200-ft. (60m) 300-ft. (90m)
- Outdoor/RF line-of-sight range: 4000-ft. (1200m) 2 miles (3200m)