

The background features a light teal color with a network diagram of white circles connected by lines. Various white icons are scattered throughout, including gears, a database cylinder, speech bubbles, a microwave, a house, a camera, a Wi-Fi router, a smartphone, a bar chart, a folder, a magnifying glass, a play button, a water drop, and a car. A central blue circle contains the text 'IoT'.

# Advanced Internet of Things Technologies

Designed by: Thuat NGUYEN-KHANH

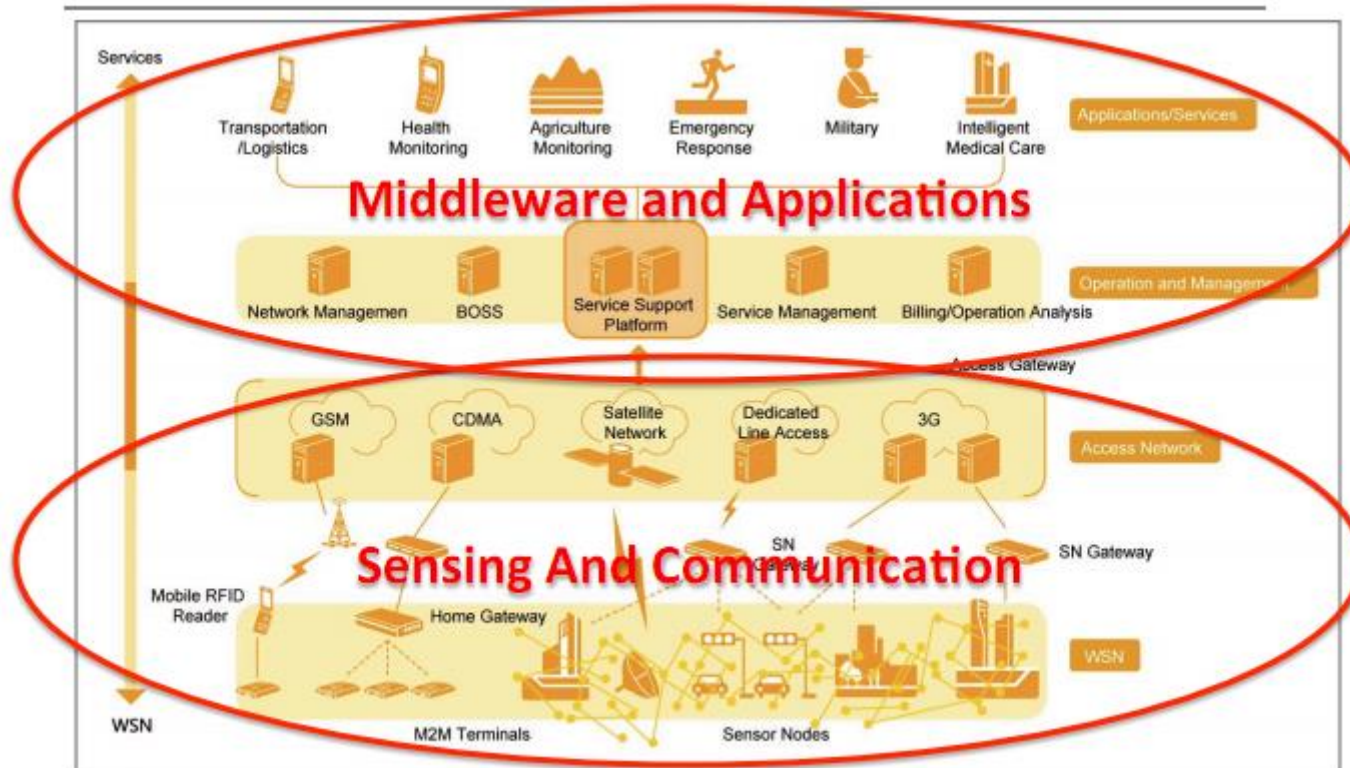
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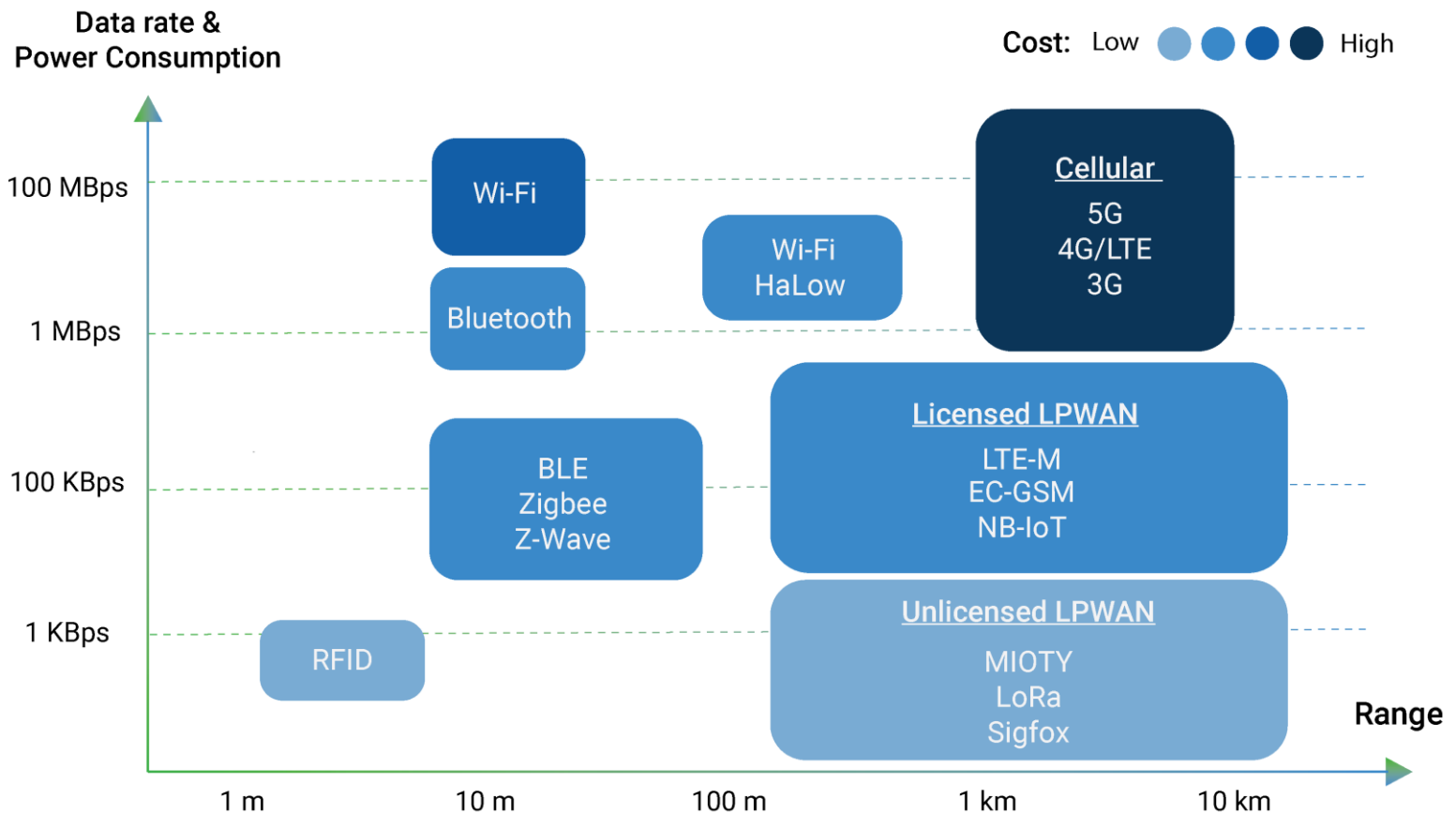
# Chapter 4: IoT Wireless Technologies

- Cellular Network Overview
- 1G/2G/3G
- 4G - LTE
- 5G
- LoRaWAN

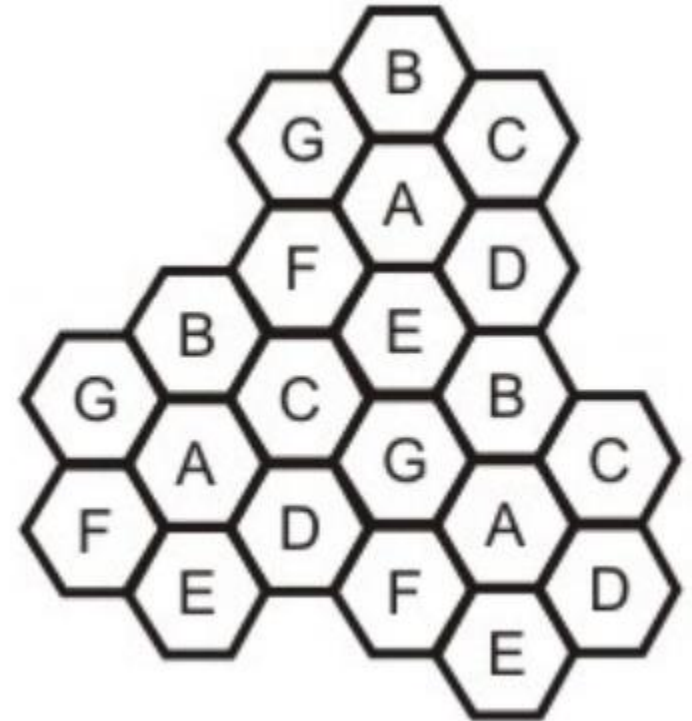
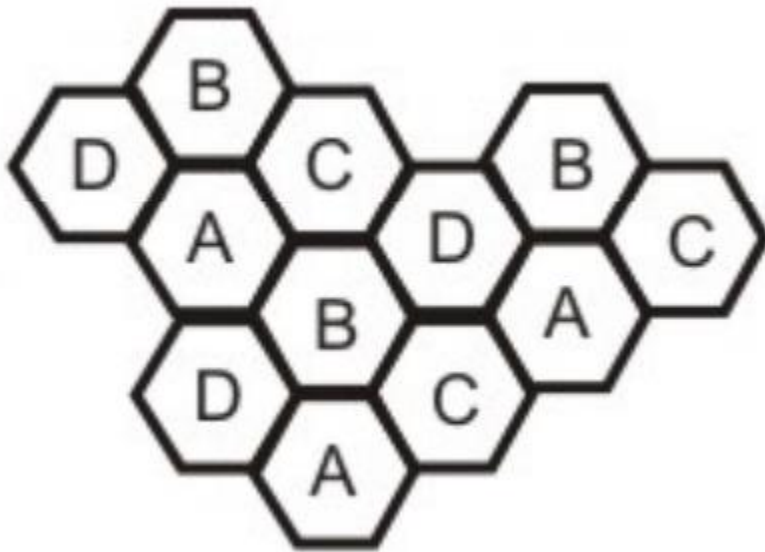
# IoT Layered Architecture



- Source: ZTE

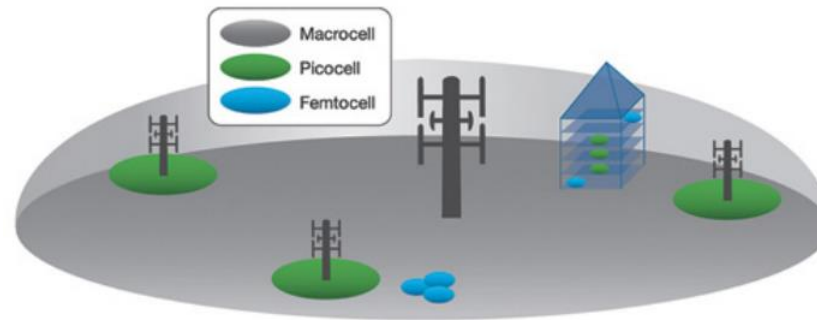


# Introduction to Cellular Networks



# Macro, Micro, Pico, Femto Cells

- Macro: Sections of a city, more than 1 km radius
- Micro: Neighborhoods, less than 1 km
- Pico: Busy public areas: Malls, airports, ..., 200 m
- Femto: Inside a home, 10 m



# Characterizing Frequency Reuse

- $D$  = minimum distance between centers of cells that use the same band of frequencies (called co-channels)
- $R$  = radius of a cell
- $d$  = distance between centers of adjacent cells ( $d = R\sqrt{3}$ )
- $N$  = number of cells in repetitious pattern (Cluster)
  - Reuse factor
  - Each cell in pattern uses unique band of frequencies

# Characterizing Frequency Reuse

- Hexagonal cell pattern, following values of N possible
  - $N = I^2 + J^2 + (I \times J)$ ,  $I, J = 0, 1, 2, 3, \dots$
- Possible values of N are 1, 3, 4, 7, 9, 12, 13, 16, 19, 21, ...
- Reuse Ratio = Distance/Radius =  $D/R = \sqrt{3N}$
- $D/d = \sqrt{N}$



# Characterizing Frequency Reuse

- Example: What would be the minimum distance between the centers of two cells with the same band of frequencies if cell radius is 1 km and the reuse factor is 12?
- $D/R = \sqrt{3N}$
- $D = (3 * 12)^{1/2} * 1 \text{ km}$
- $D = 6 \text{ km}$

# Introduction to Cellular Networks



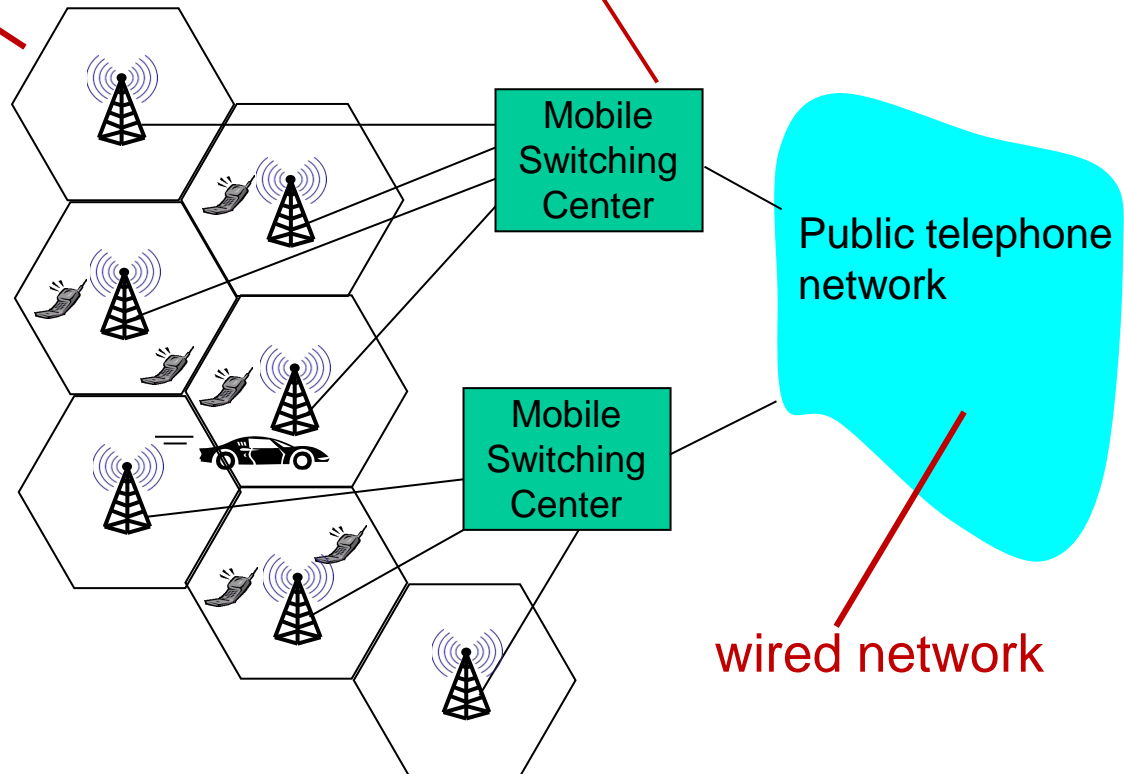
# Components of cellular network architecture

## cell

- ❖ covers geographical region
- ❖ *base station* (BS)  
analogous to 802.11 AP
- ❖ *mobile users* attach to network through BS
- ❖ *air-interface*: physical and link layer protocol between mobile and BS

## MSC

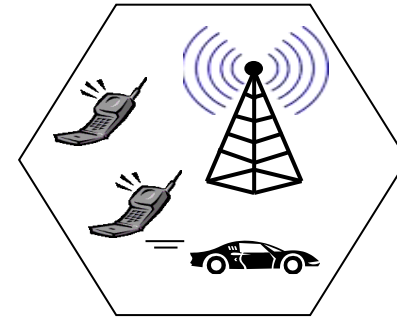
- ❖ connects cells to wired tel. net.
- ❖ manages call setup (more later!)
- ❖ handles mobility (more later!)



# Cellular networks: the first hop

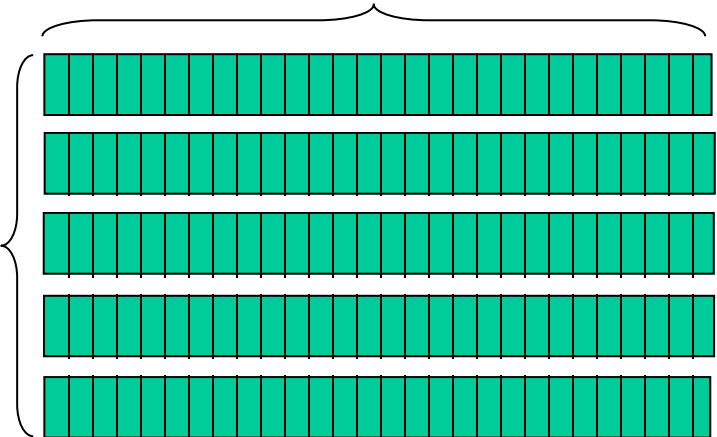
Two techniques for sharing mobile-to-BS radio spectrum

- **combined FDMA/TDMA:** divide spectrum in frequency channels, divide each channel into time slots
- **CDMA:** code division multiple access



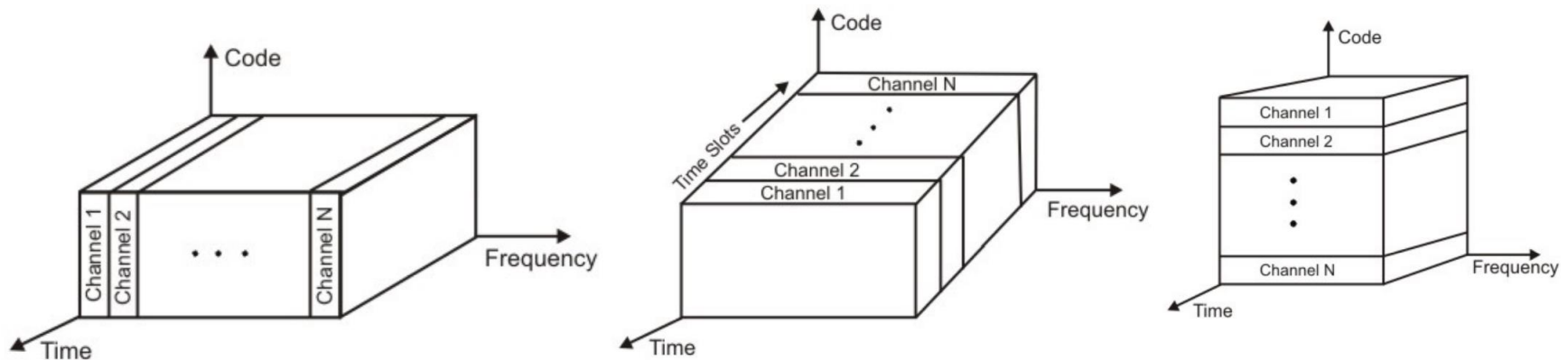
time slots

frequency bands

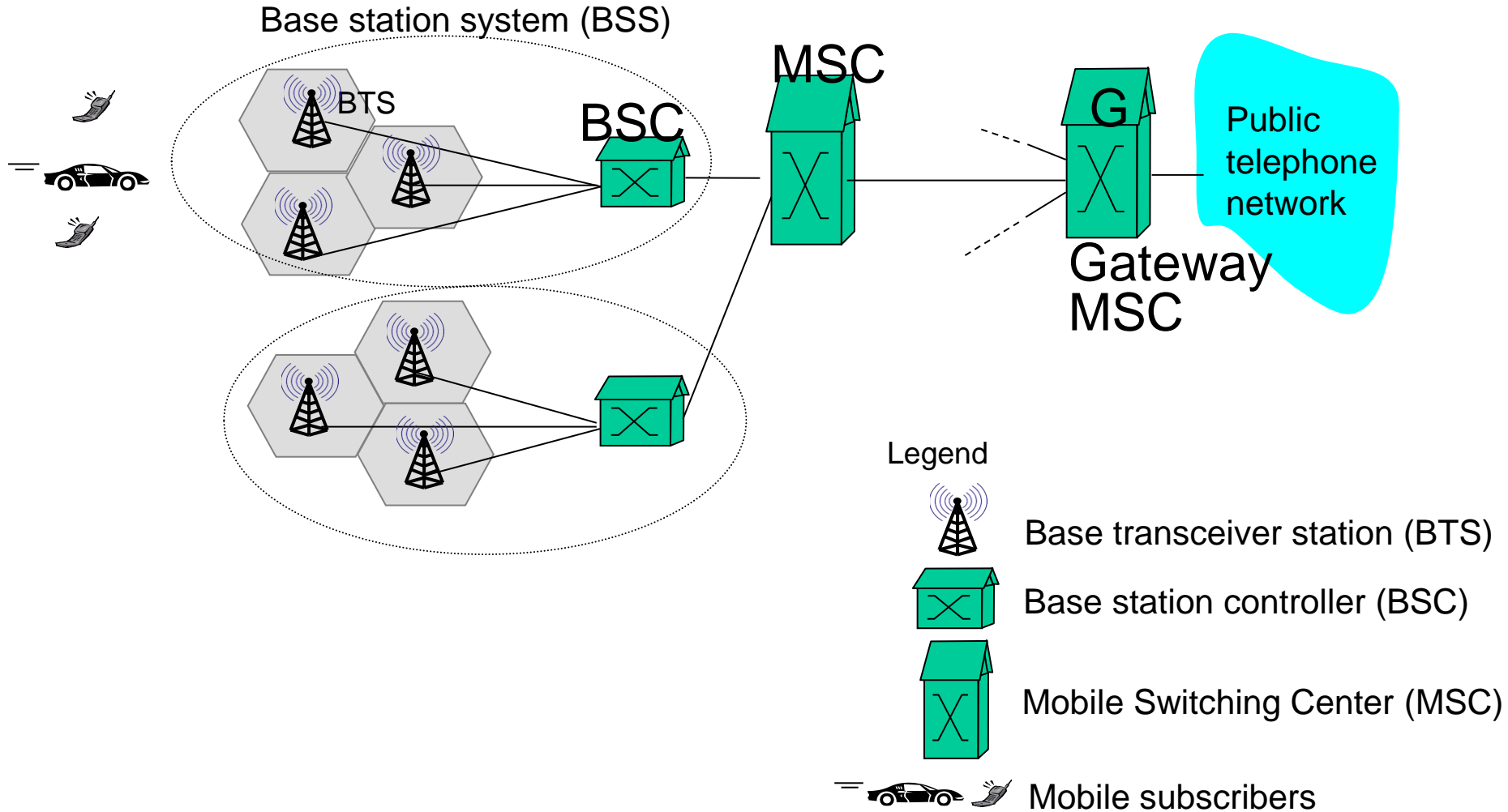


# Medium Access Control

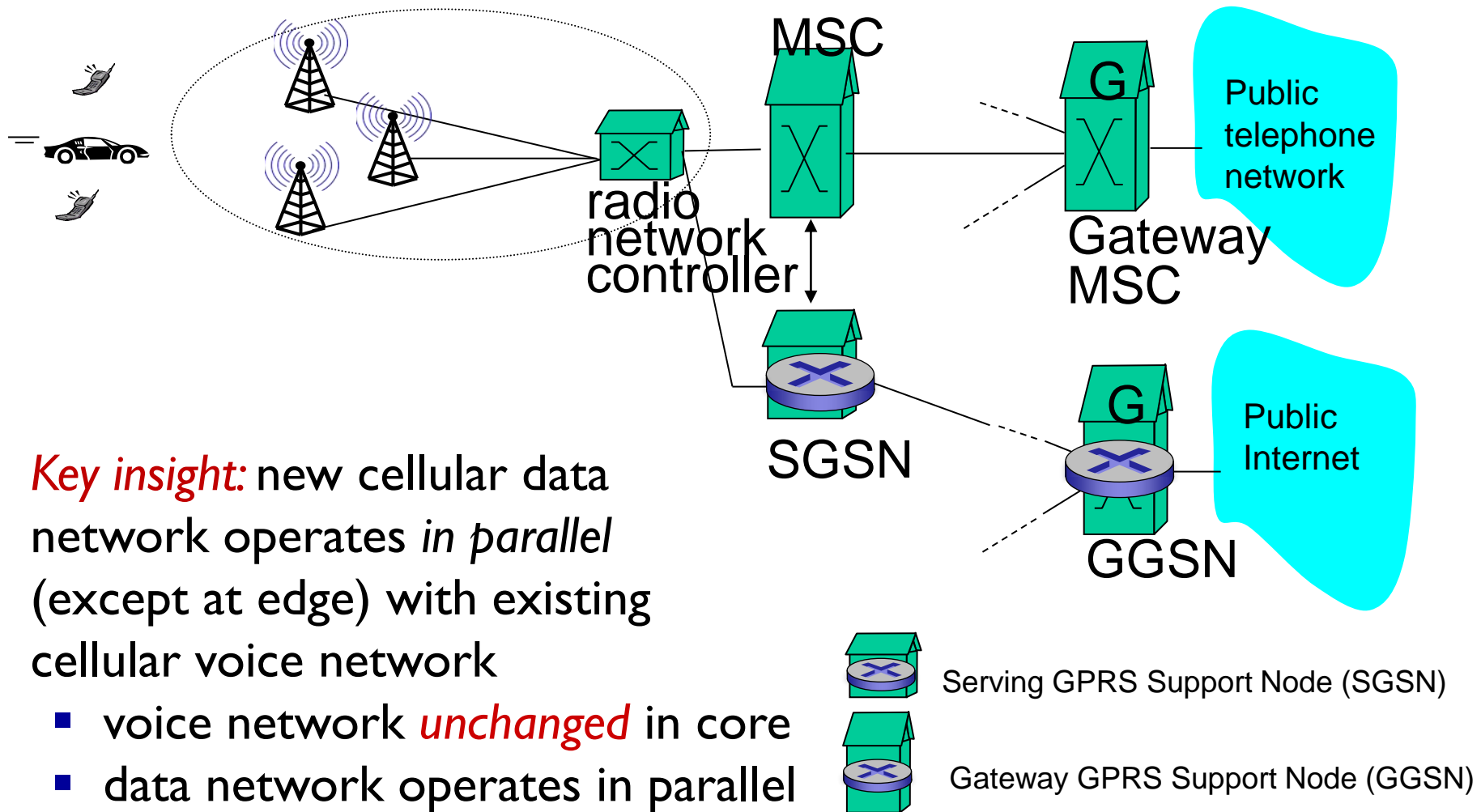
- FDMA: Frequency Division Multiple Access
- TDMA: Time Division Multiple Access
- CDMA: Code Division Multiple Access



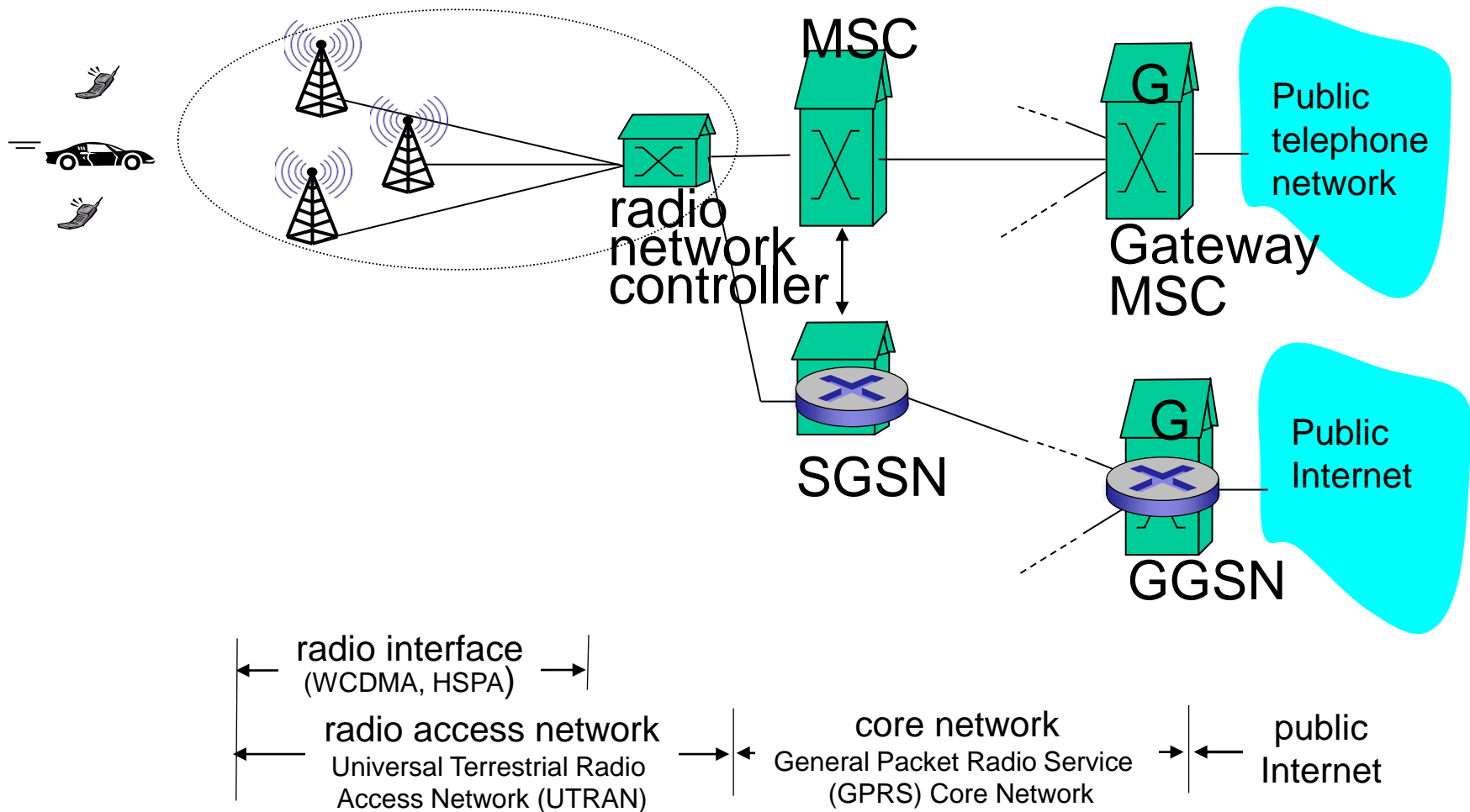
# 2G (voice) network architecture



# 3G (voice+data) network architecture

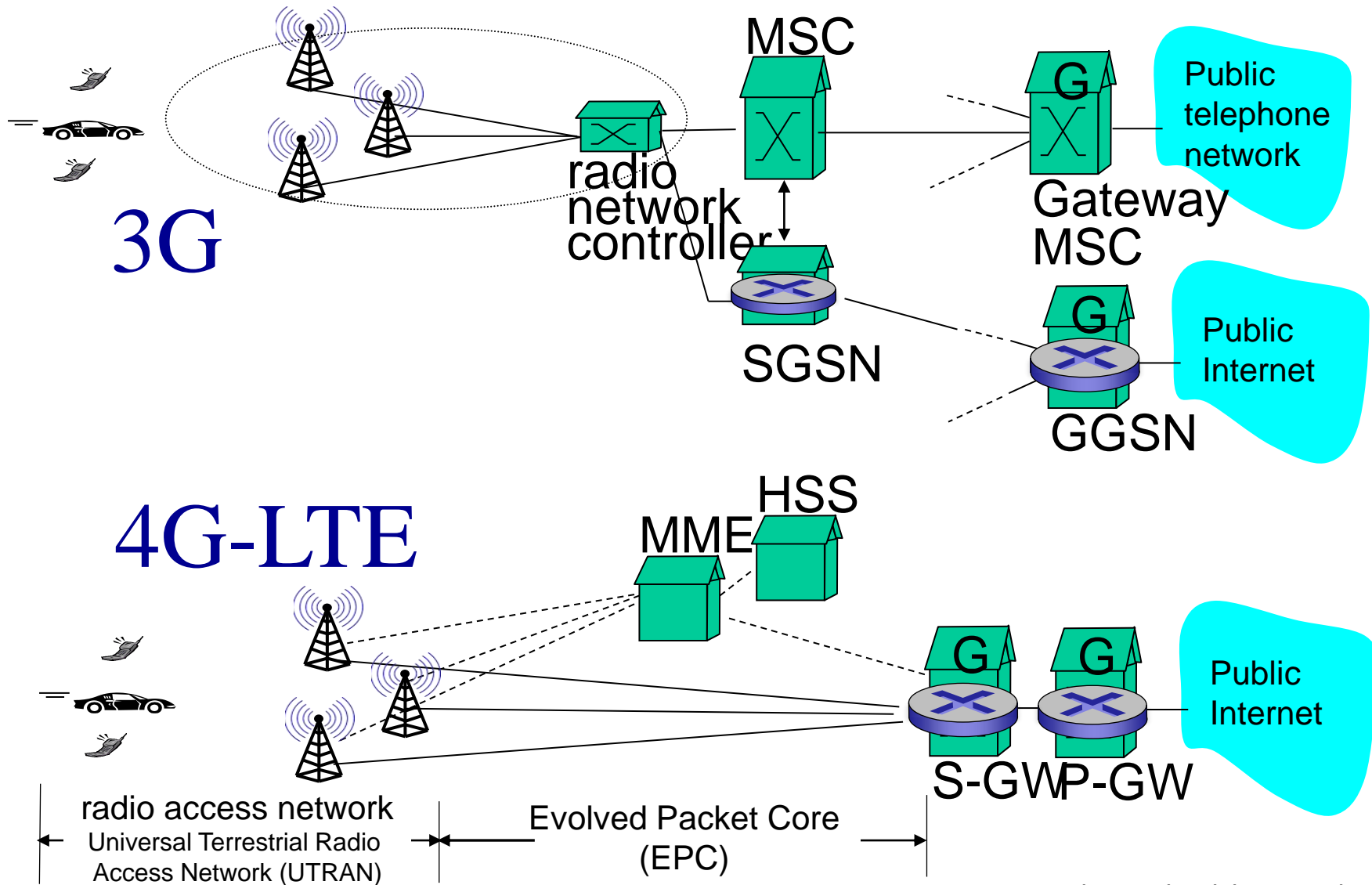


# 3G (voice+data) network architecture



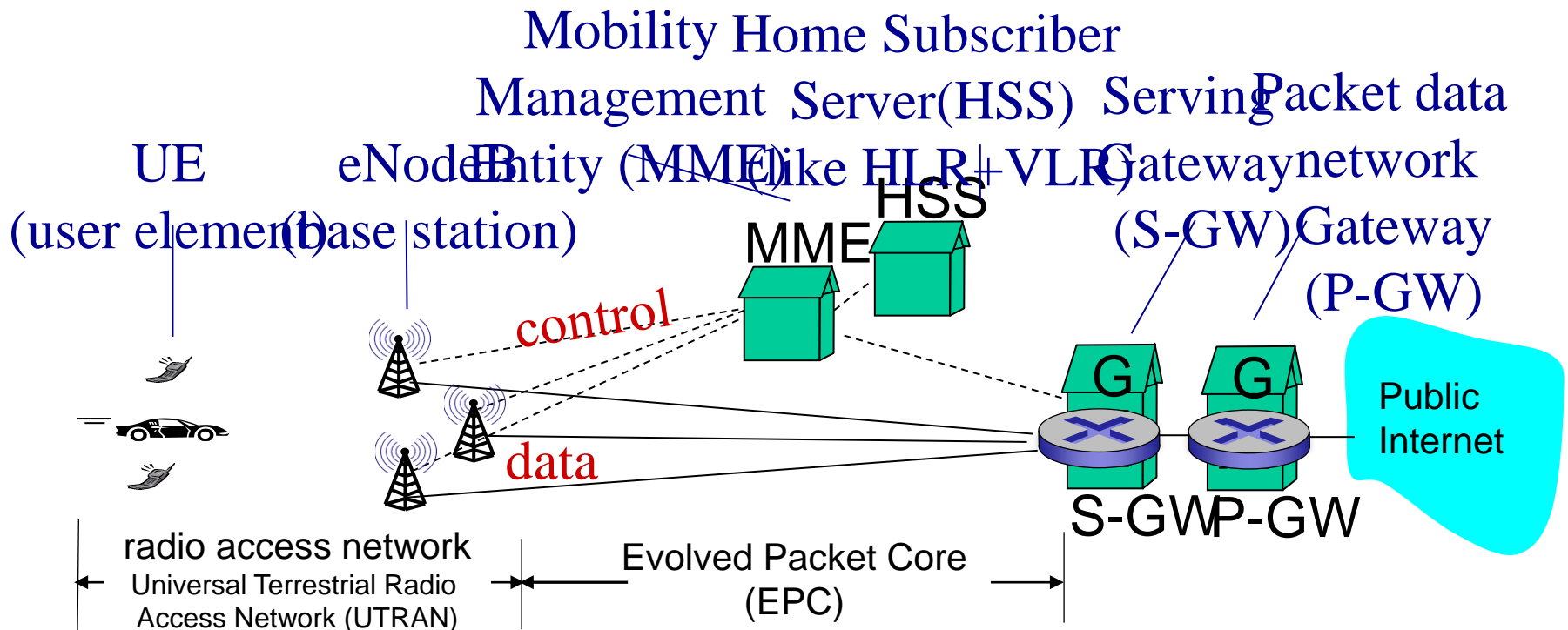


# 3G versus 4G LTE network architecture

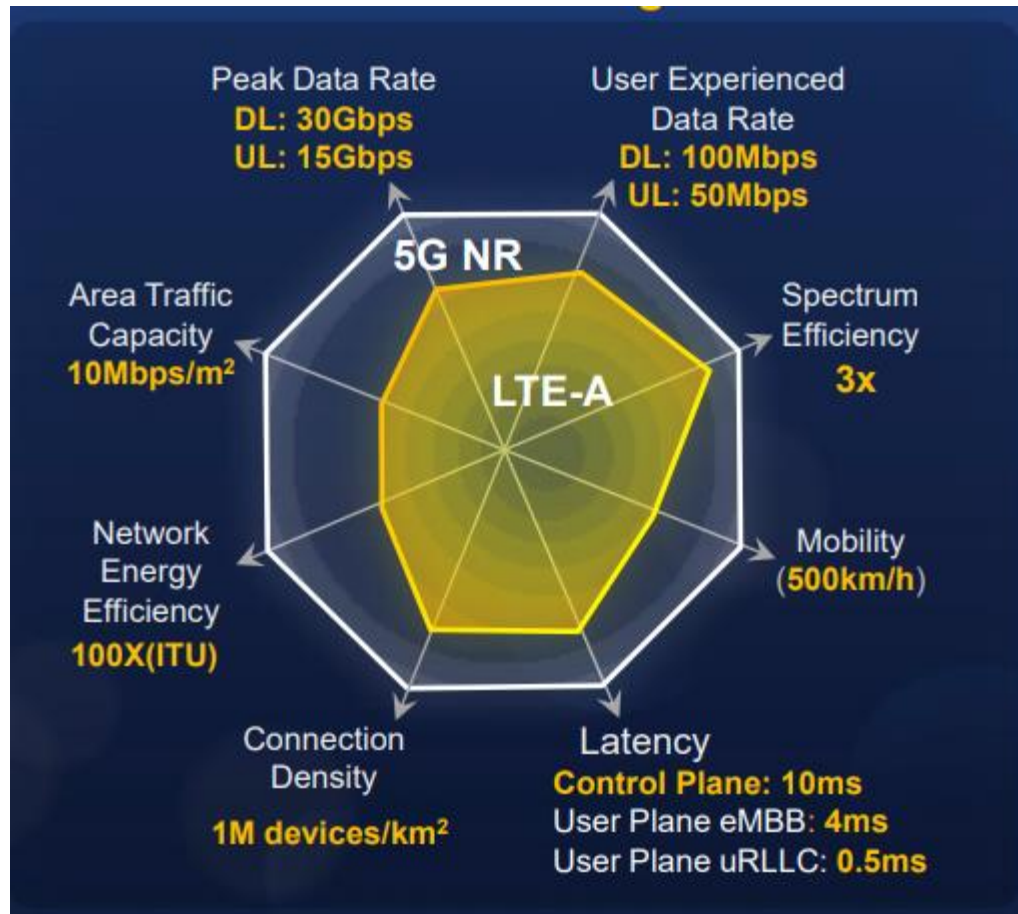


# 4G: differences from 3G

- all IP core: IP packets tunneled (through core IP network) from base station to gateway
- no separation between voice and data – all traffic carried over IP core to gateway



# 5G Definition



# The vision of 5G

## 5G will provide all the means to access the Internet, including

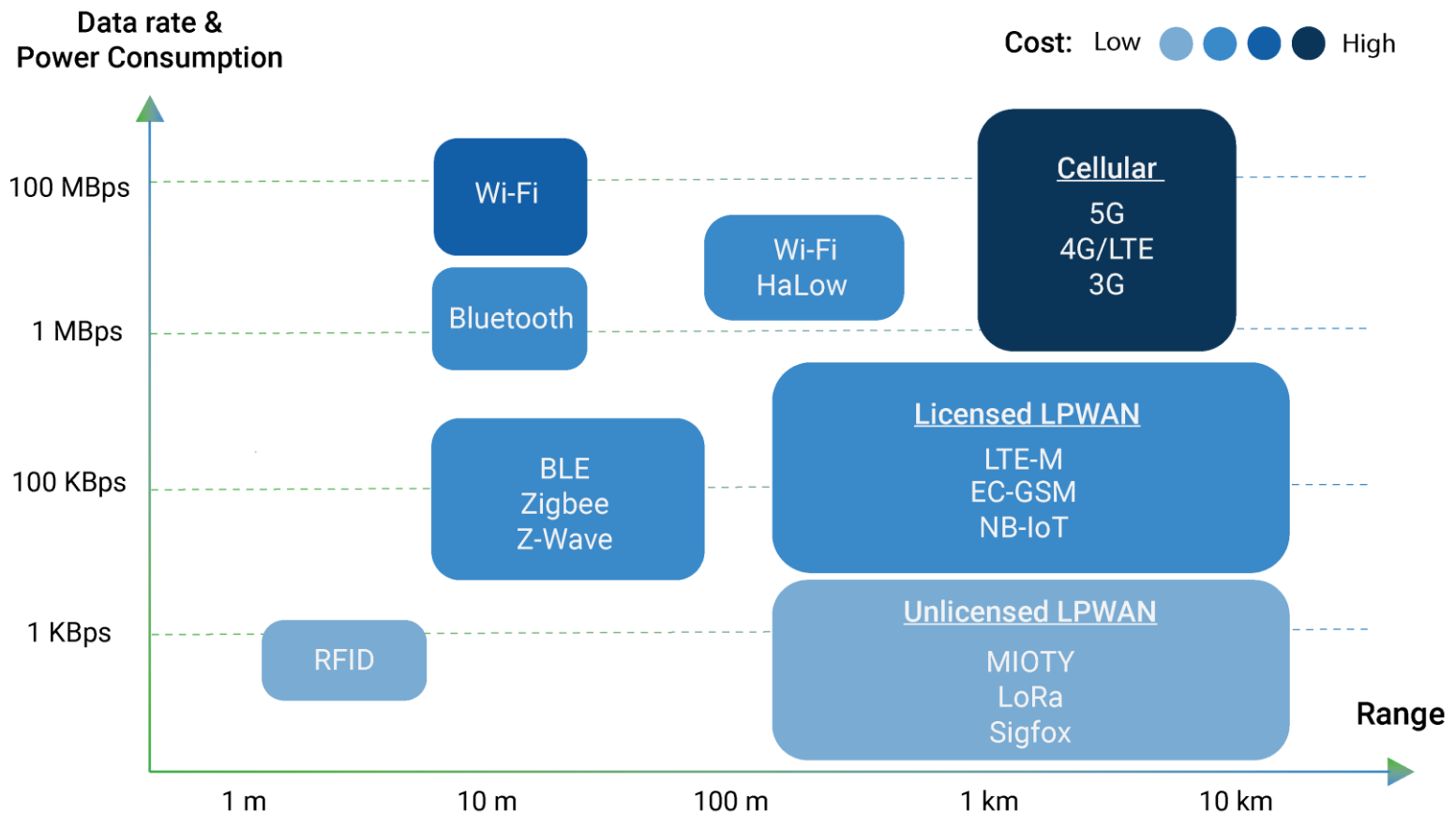
- radio: existing (4G, Wi-Fi) and a new radio (NR)
- a convergent core network managing fixed and radio accesses (fibre, 4G, NR, Wi-Fi...)

## 5G will deliver more than connectivity

- new business models and value propositions
- enabled by a unified infrastructure integrating networking, computing and storage resources

## For high performance and new capabilities





# LoRa, LoRaWAN, LPWAN

- LPWAN name for Low Power Wide-Area Network
  - a wireless wide area network technology that is specialized for interconnecting devices with low-bandwidth connectivity, focusing on range and power efficiency.
  - Mostly unlicensed (but regulated) spectrum under 1 GHz (433, 868, 915 MHz)
  - Multiple solutions, including:





**Long battery  
life**



**Support for a  
massive  
number of  
devices**

**Low device  
cost**

**LPWAN**

**Extended  
coverage (10-15  
km in rural areas,  
2-5 km in urban  
areas)**

**Low cost and  
easy  
deployment**



# LoRa, LoRaWAN, LPWAN

- LoRa = Long Range
  - Wireless modulation technology
  - Physical layer for long range communications
  - Low bandwidth, Low battery usage



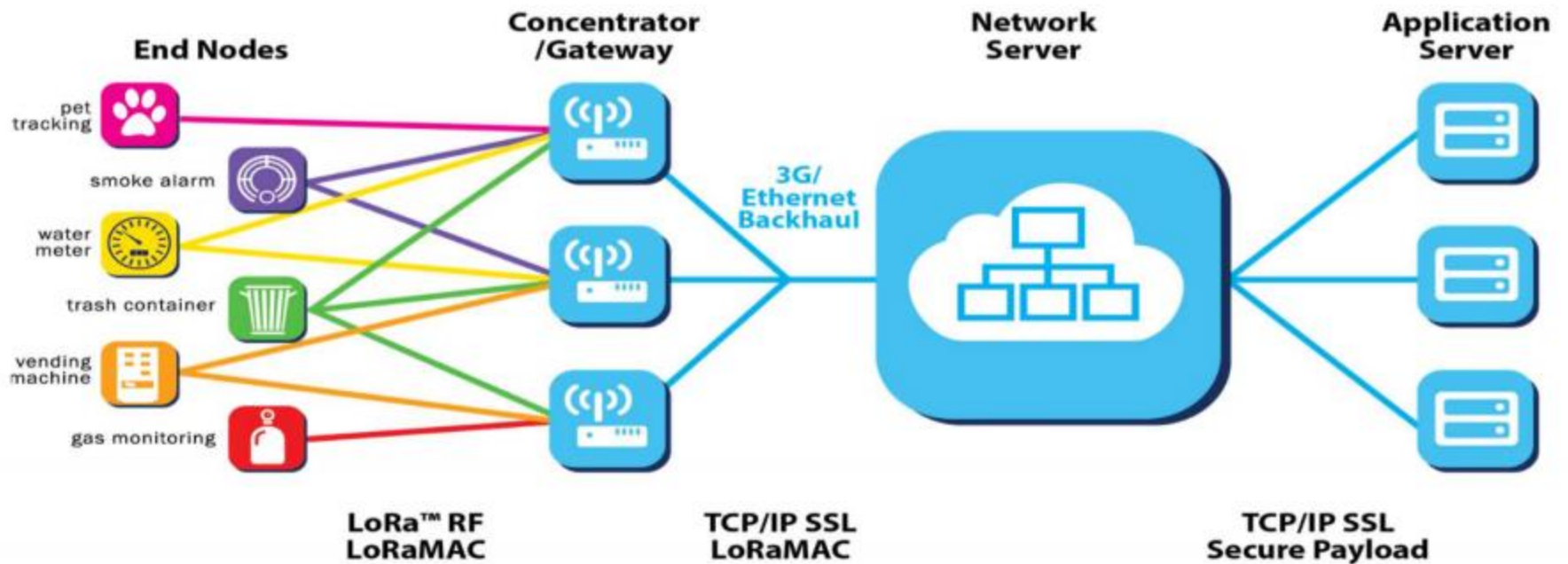
# LoRa, LoRaWAN, LPWAN

- LoRa = Long Range
  - Operates in the license-free ISM bands all around the world
    - 433, 868, 915 Mhz
    - Regulated (power, duty-cycle, bandwidth)
    - EU: 0.1% or 1% per sub-band duty-cycle limitation (per hour)
  - Sensitivity: -142 dBm
  - Link budget (EU): 156 dB

# LoRa, LoRaWAN, LPWAN

- LoRaWAN
  - Communications protocol and architecture that utilizes the LoRa physical layer
  - Data rates are defined that range from 300bps to 5.5kbps
    - with two high-speed channels at 11kbps and 50kbps (FSK modulation)
  - Supports: secure bi-directional communication, mobility and localization.

# LoRaWAN





**LoPy**

868/915 MHz  
ESP32  
WiFi/BLE  
4 MB Flash  
Python



**LORA GPS Hat**

868/433/915 MHz  
LoRa  
GPS  
SPI  
Raspberry Pi 2/3



**RN2483**

868/433 MHz  
Microchip



**Wasp mote**

Libelium  
868/915 MHz  
C/C++



**mDot**

868/433/915 MHz

# Summary

- Review IoT communication protocols
- Introduction to 1, 2, 3, 4-LTE, 5 Generation networks
  - Analog/Digital signal
  - Network architectures
- LoRa, LoRaWAN, LPWAN
  - LPWAN is Low Power Wide-Area Network
  - LoRa is a Wireless modulation technology
  - LoRaWAN is a communications protocol and architecture that utilizes the LoRa physical layer

