

**RNV**

# **Vehicular Communications – Part II**

## **Radio Networks for Vehicular Communications**

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# Outline

1. **Network Architectures: Evolution From GSM towards 5G**
2. **Mobility Management**
3. **2G (GSM): Numerology**
4. **2.5G (GPRS)**
5. **3G (UMTS): Numerology**
6. **LTE: Numerology**
7. **Application to Vehicular Communications**

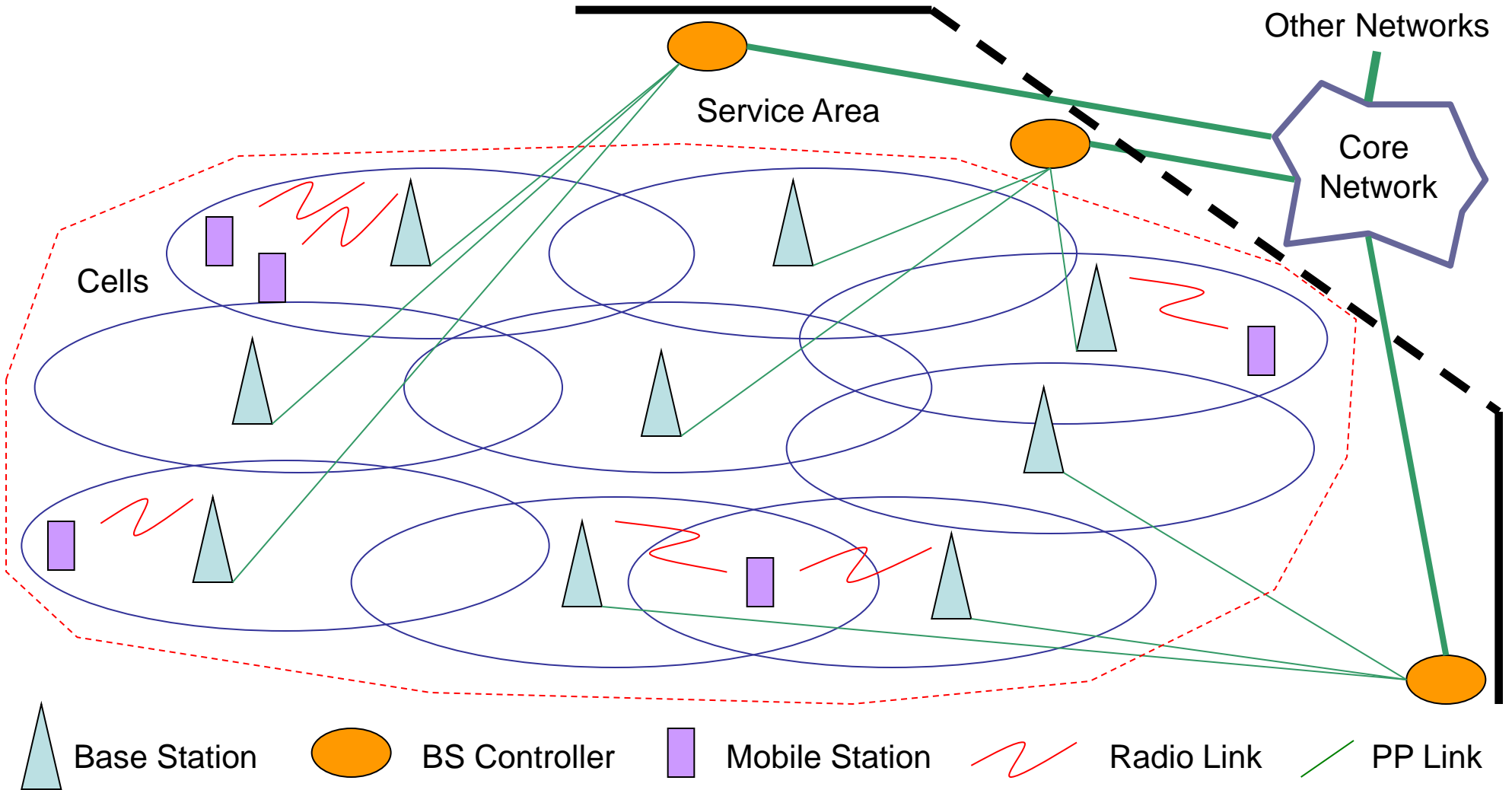
**The scope of this lecture block is to introduce the fundamentals of network architectures for mobile radio networks.**

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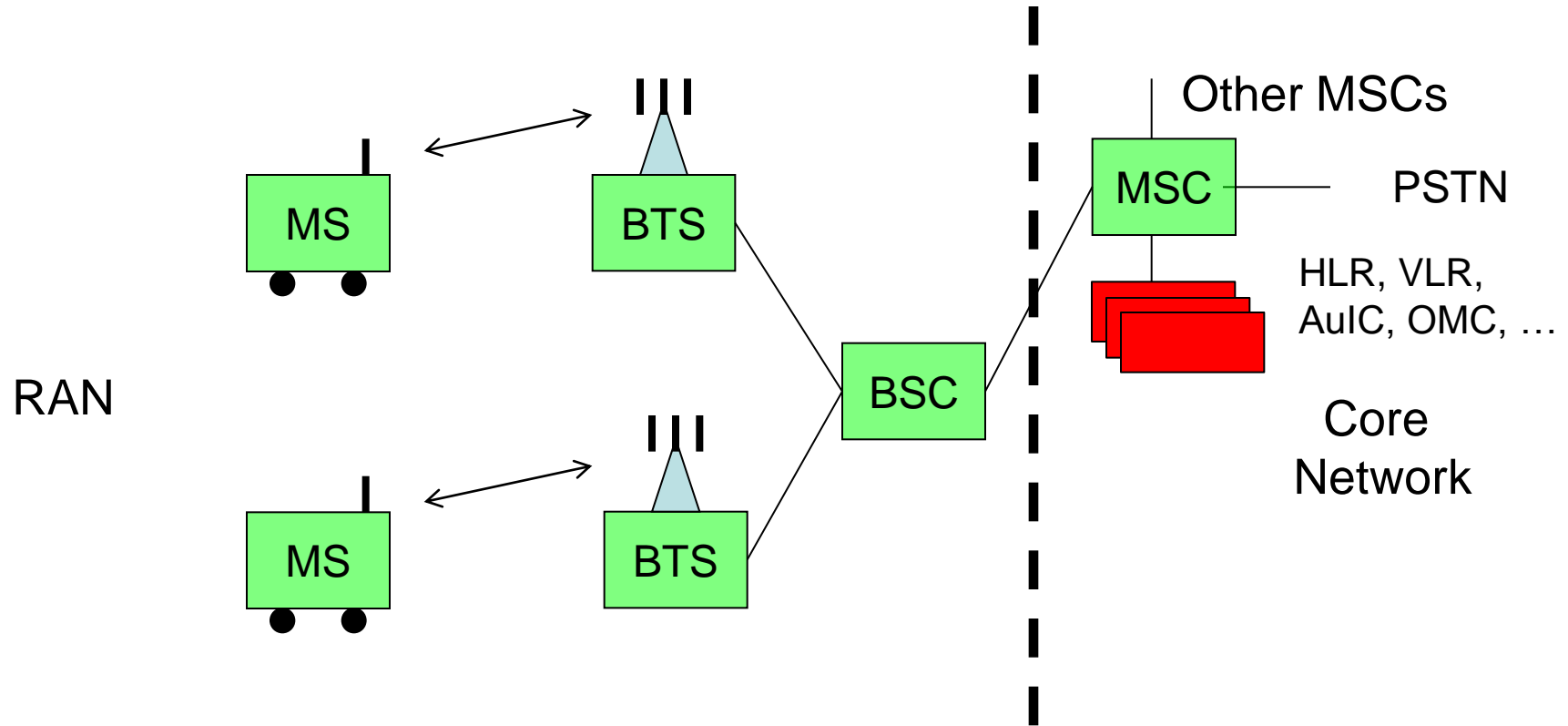
# 1. Network Architectures

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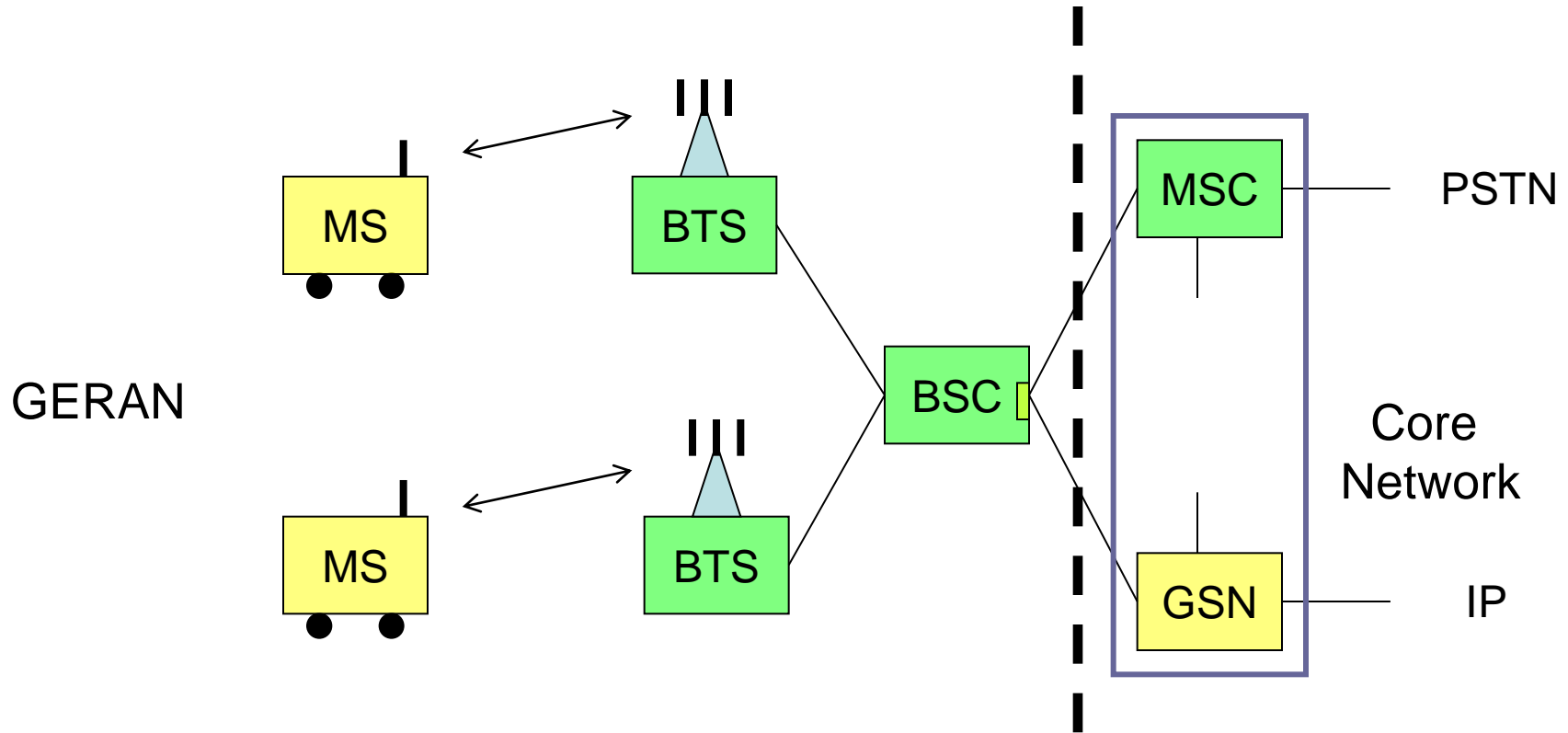
# RAN Architecture: 2G



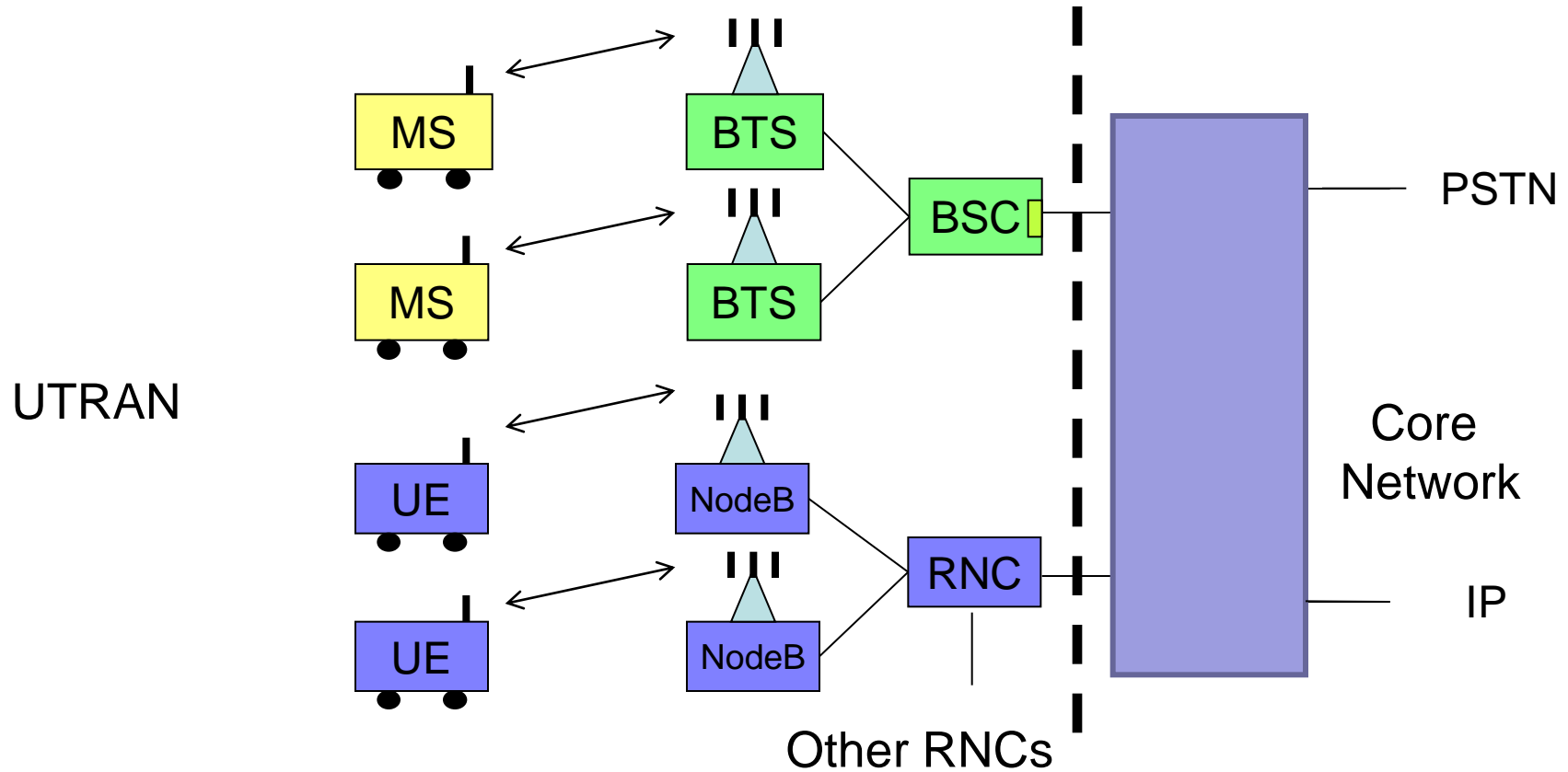
# Network Architecture: 2G



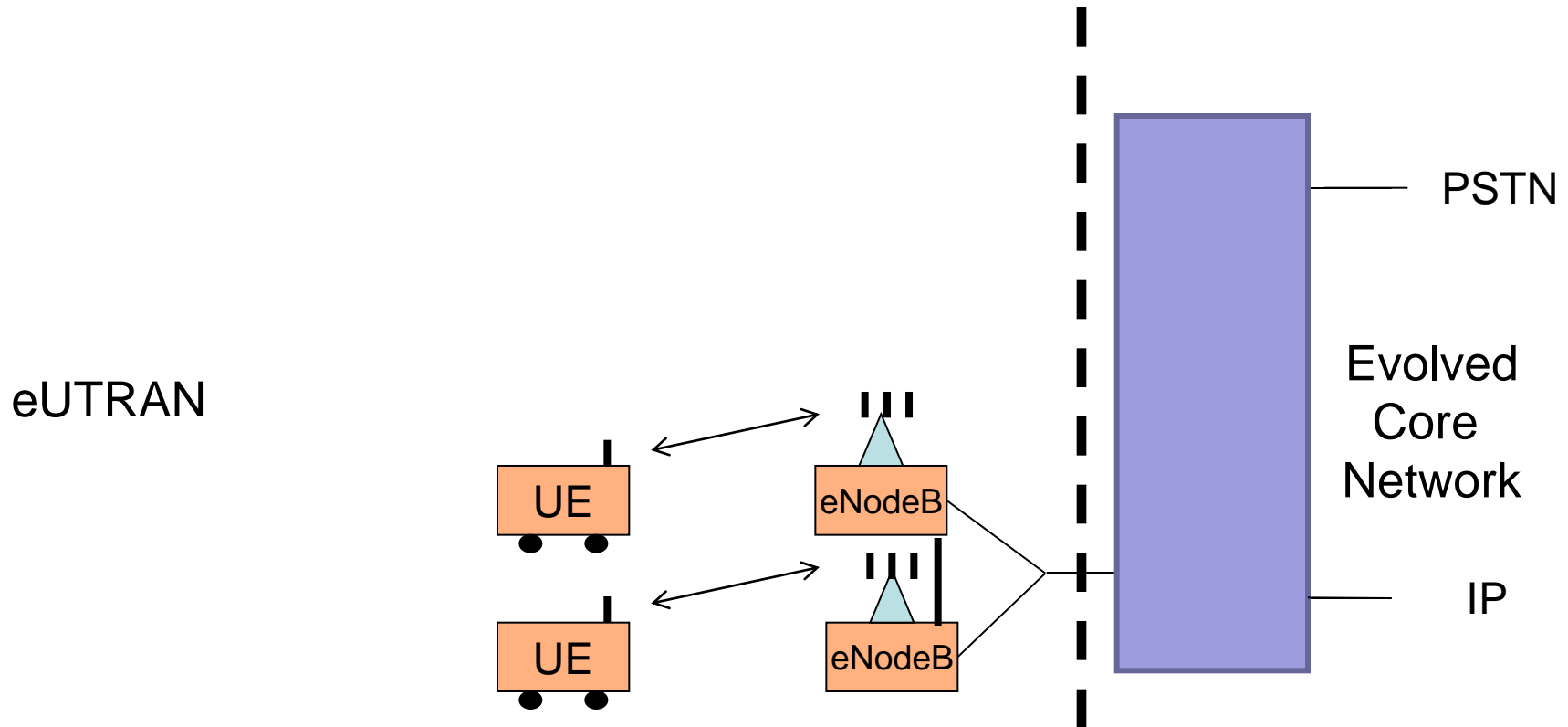
# Network Architecture: 2.5G



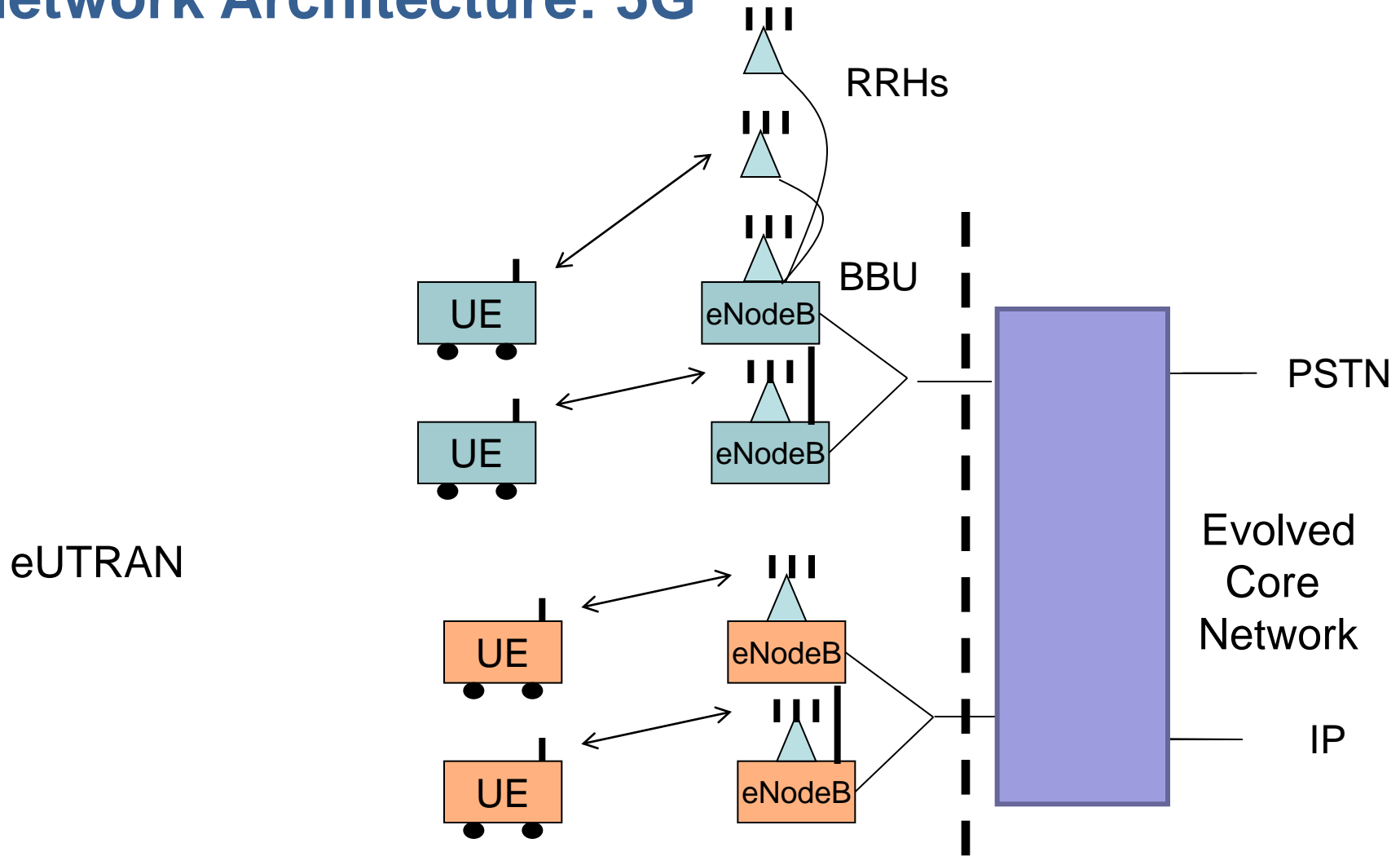
# Network Architecture: 3G



# Network Architecture: LTE (4G)



# Network Architecture: 5G

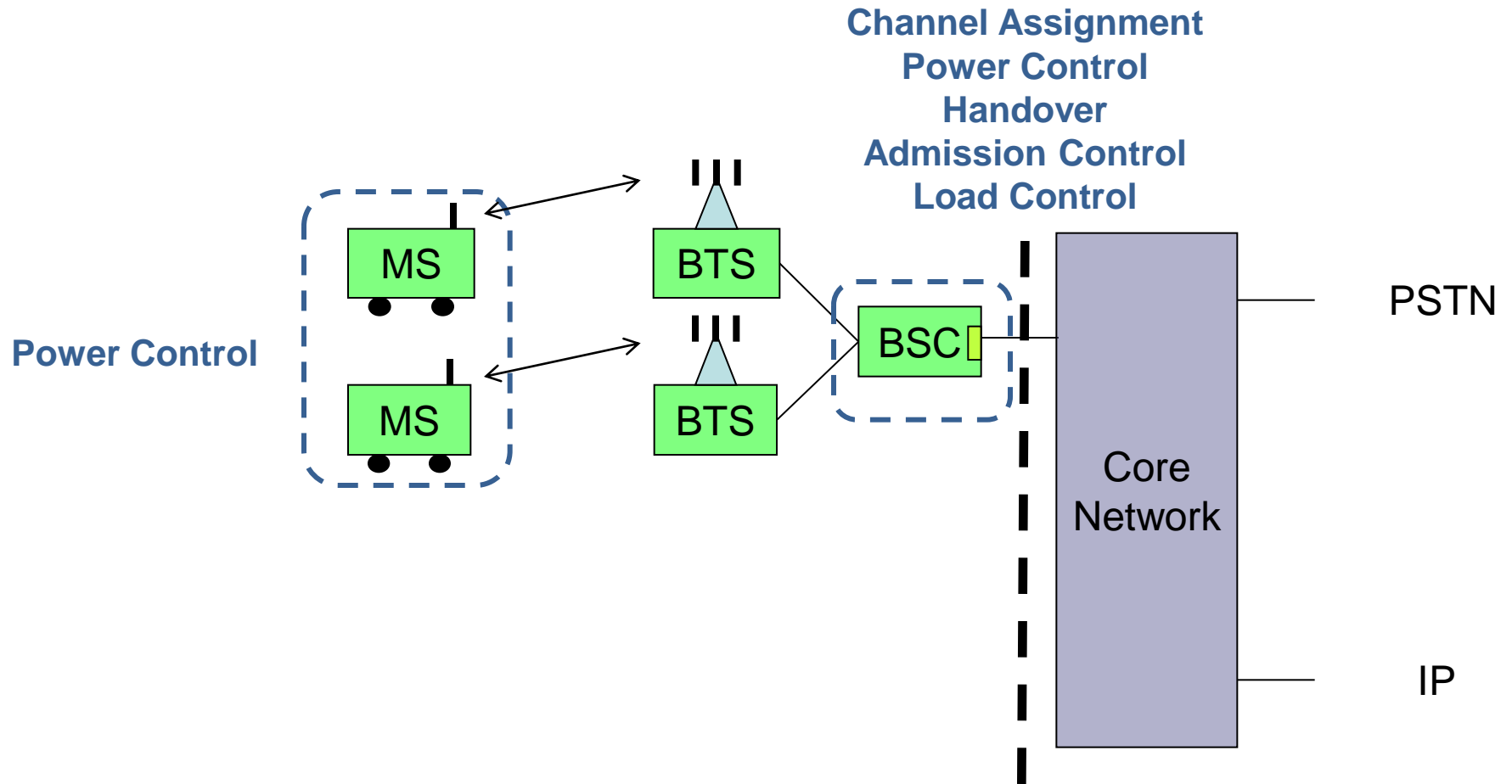


# Radio Resource Management

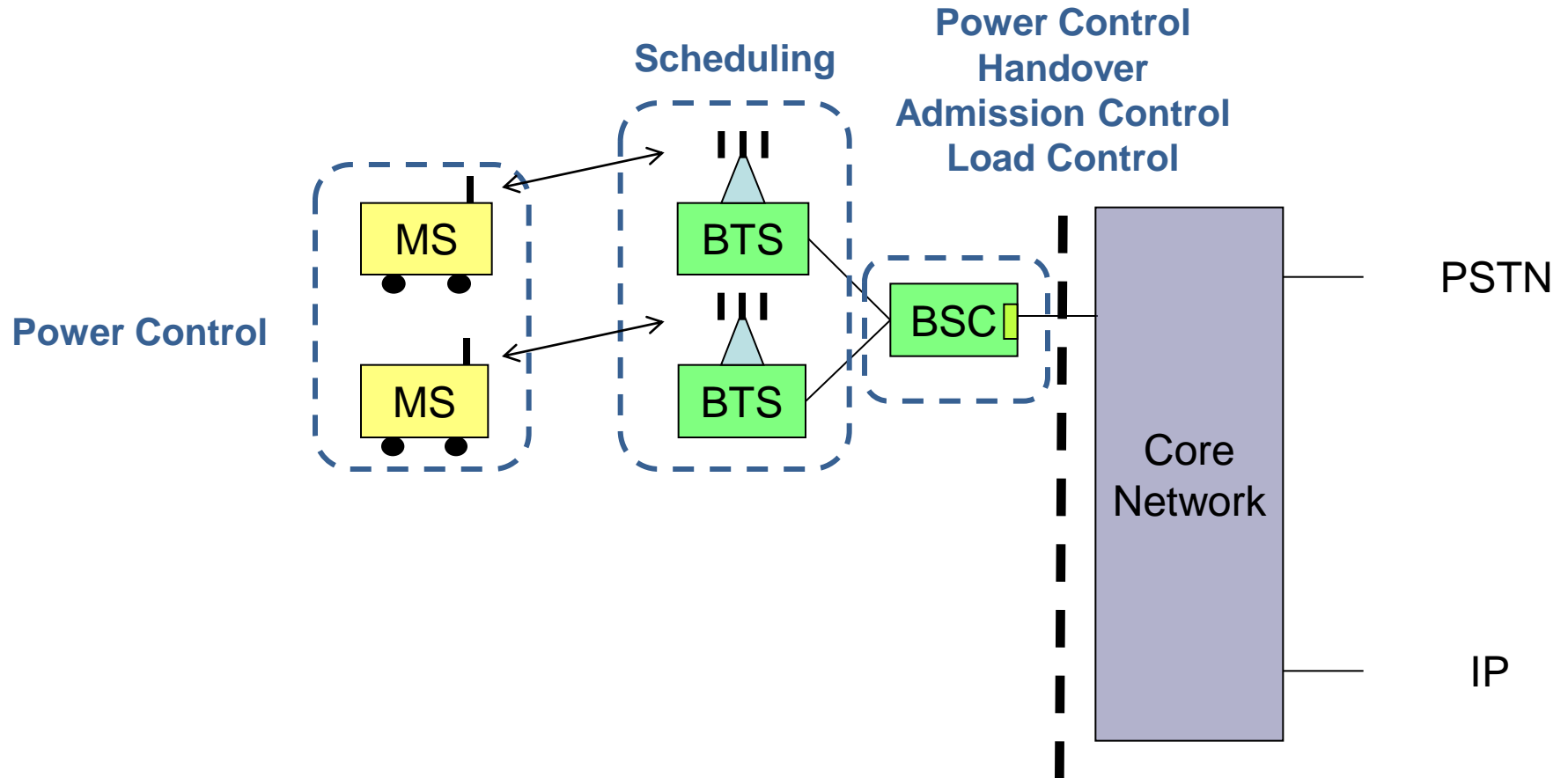
<b>Admission Control</b>	<b>The process of determining whether a service request can be admitted to the system</b>
<b>Directed Retry</b>	<b>The process of re-directing a new user toward a base station different from the one providing best link budget</b>
<b>Channel Allocation</b>	<b>The process of choosing the channel (and the number of RUs) to be allocated to the user</b>
<b>Power Control</b>	<b>The process of setting the transmission power level</b>
<b>Hard Handover</b>	<b>The process of changing serving base and/or channel</b>
<b>Soft Handover</b>	<b>The process of modifying the set of serving bases</b>
<b>Load Control</b>	<b>The process of controlling the load of the network</b>

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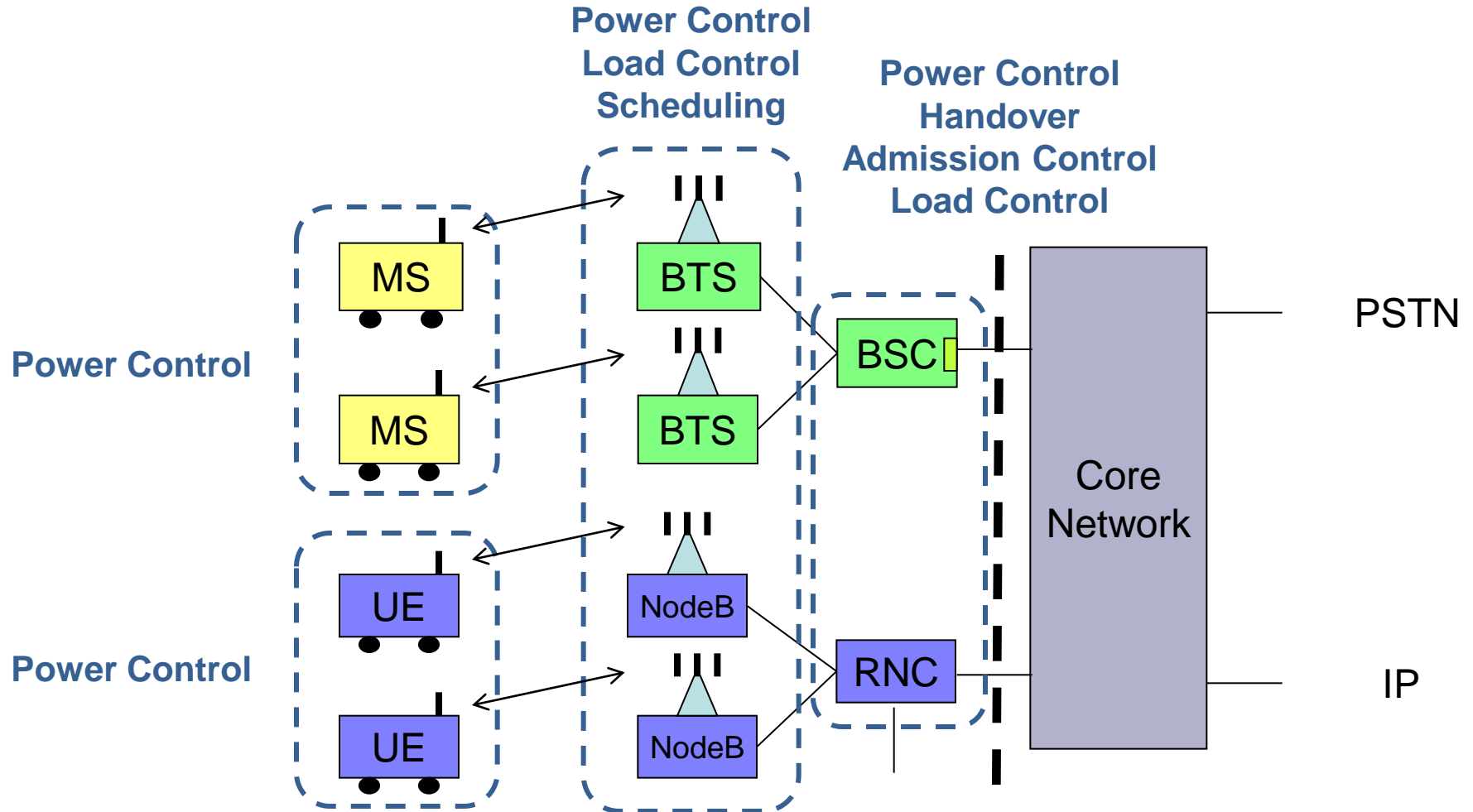
# Network Architecture: 2G



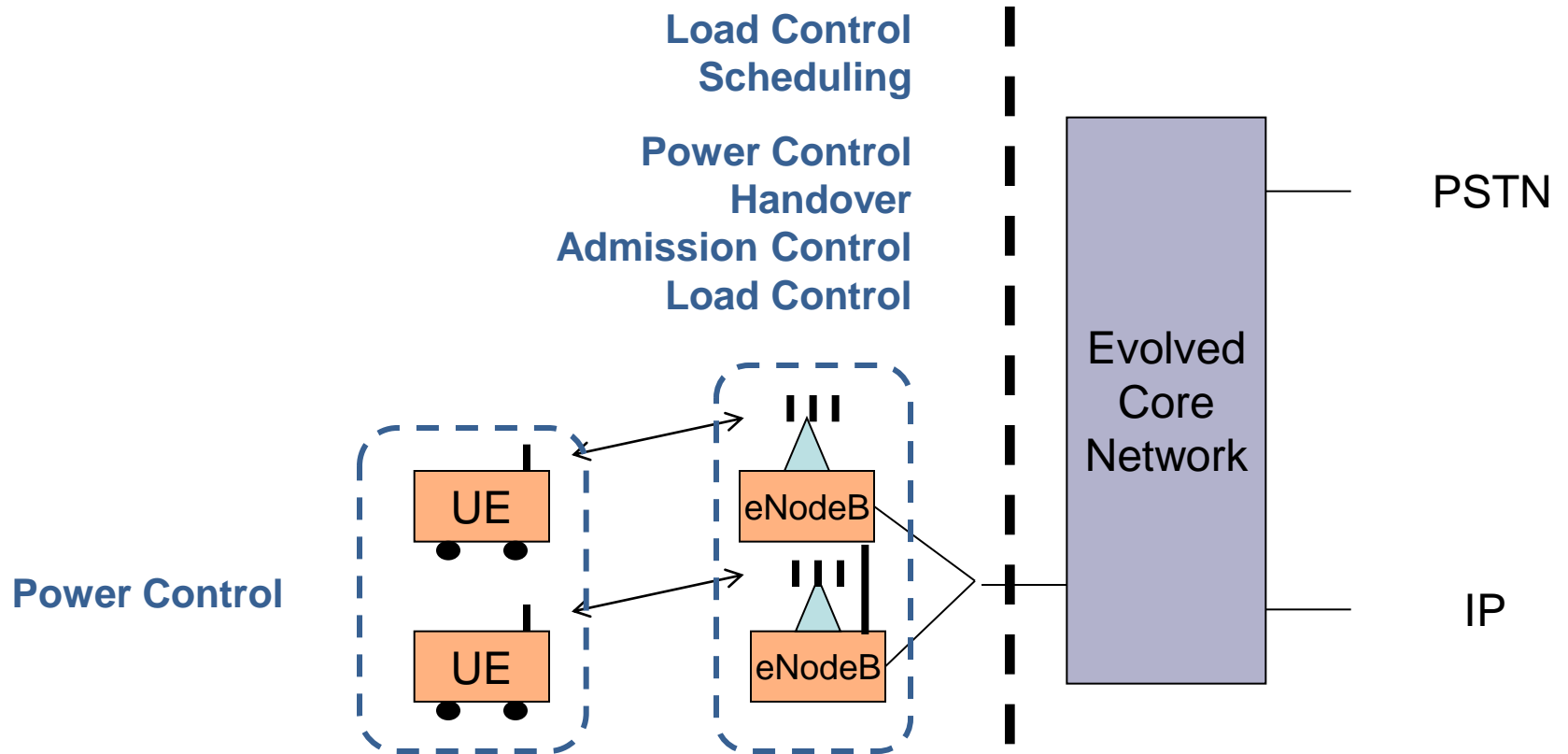
# Network Architecture: 2.5G



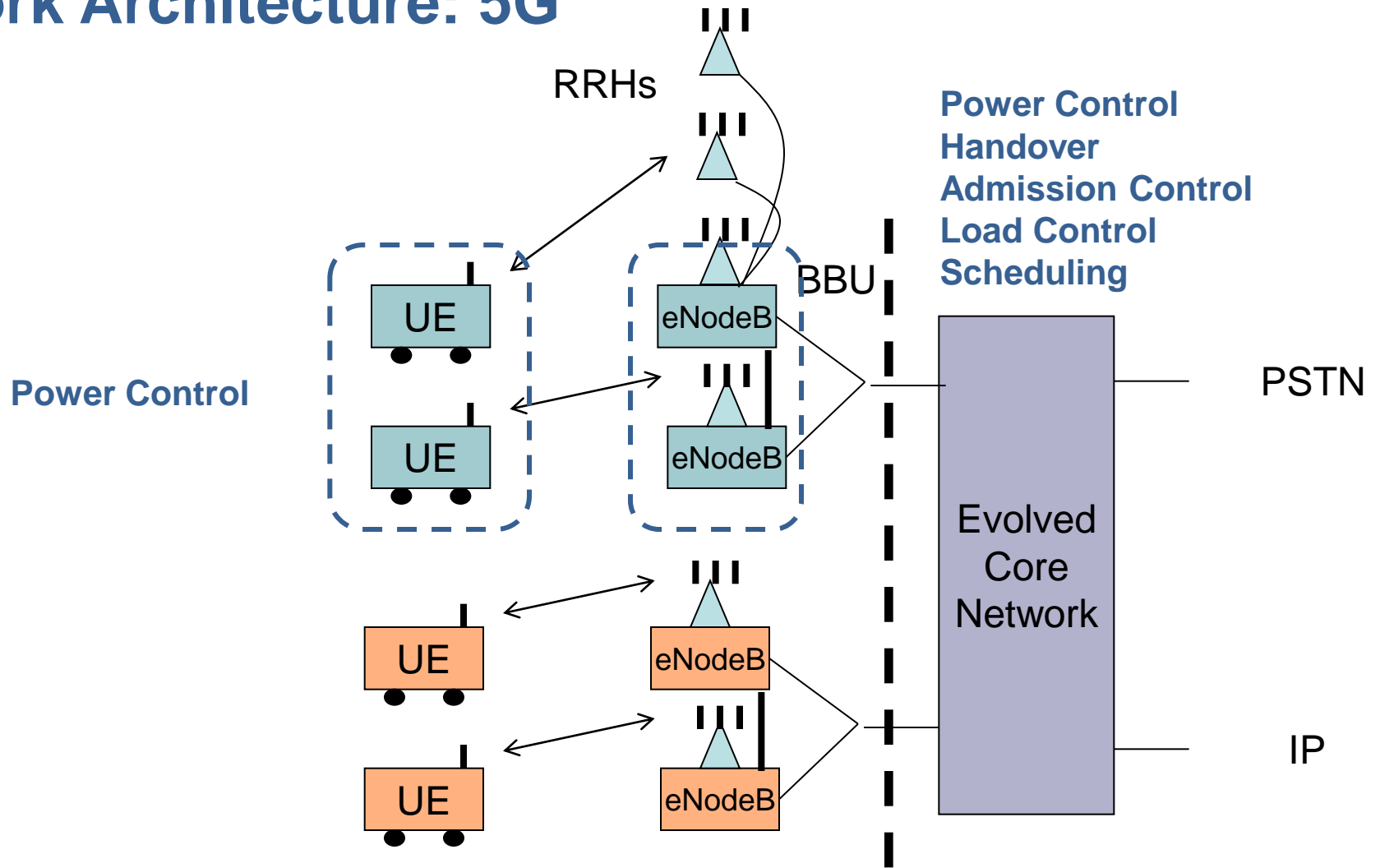
# Network Architecture: 3G



# Network Architecture: LTE (4G)

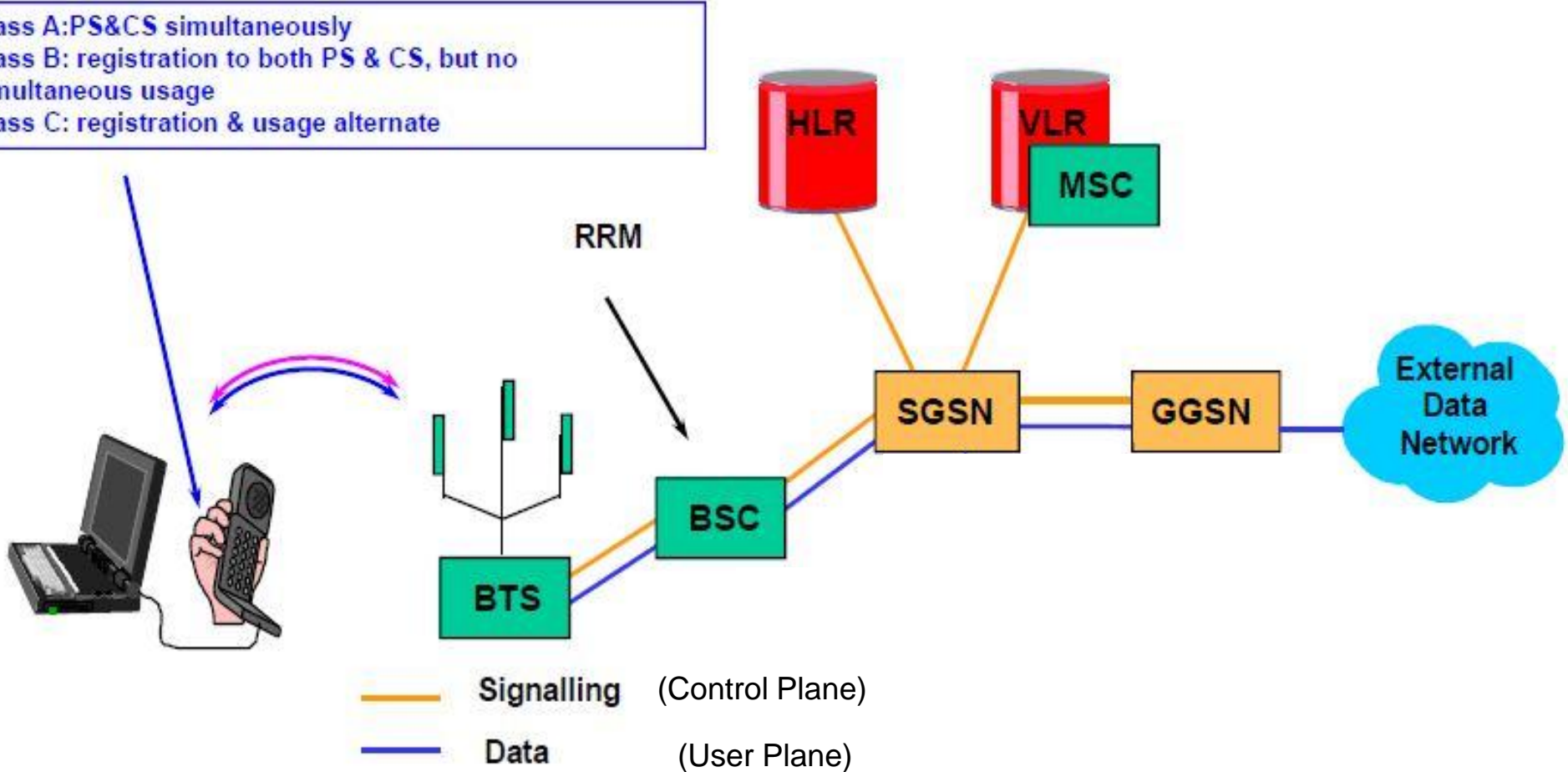


# Network Architecture: 5G

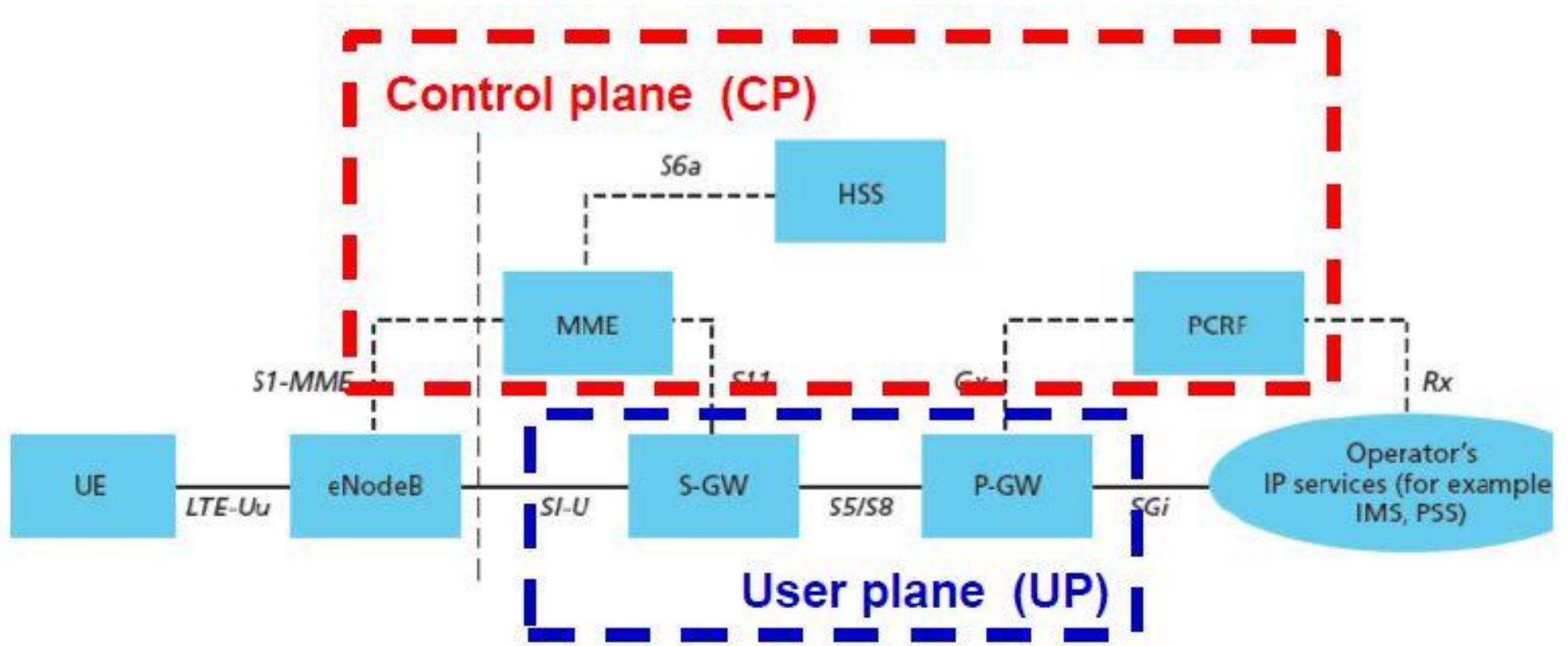


# CN Architecture: 2.5G

Class A: PS&CS simultaneously  
 Class B: registration to both PS & CS, but no simultaneous usage  
 Class C: registration & usage alternate



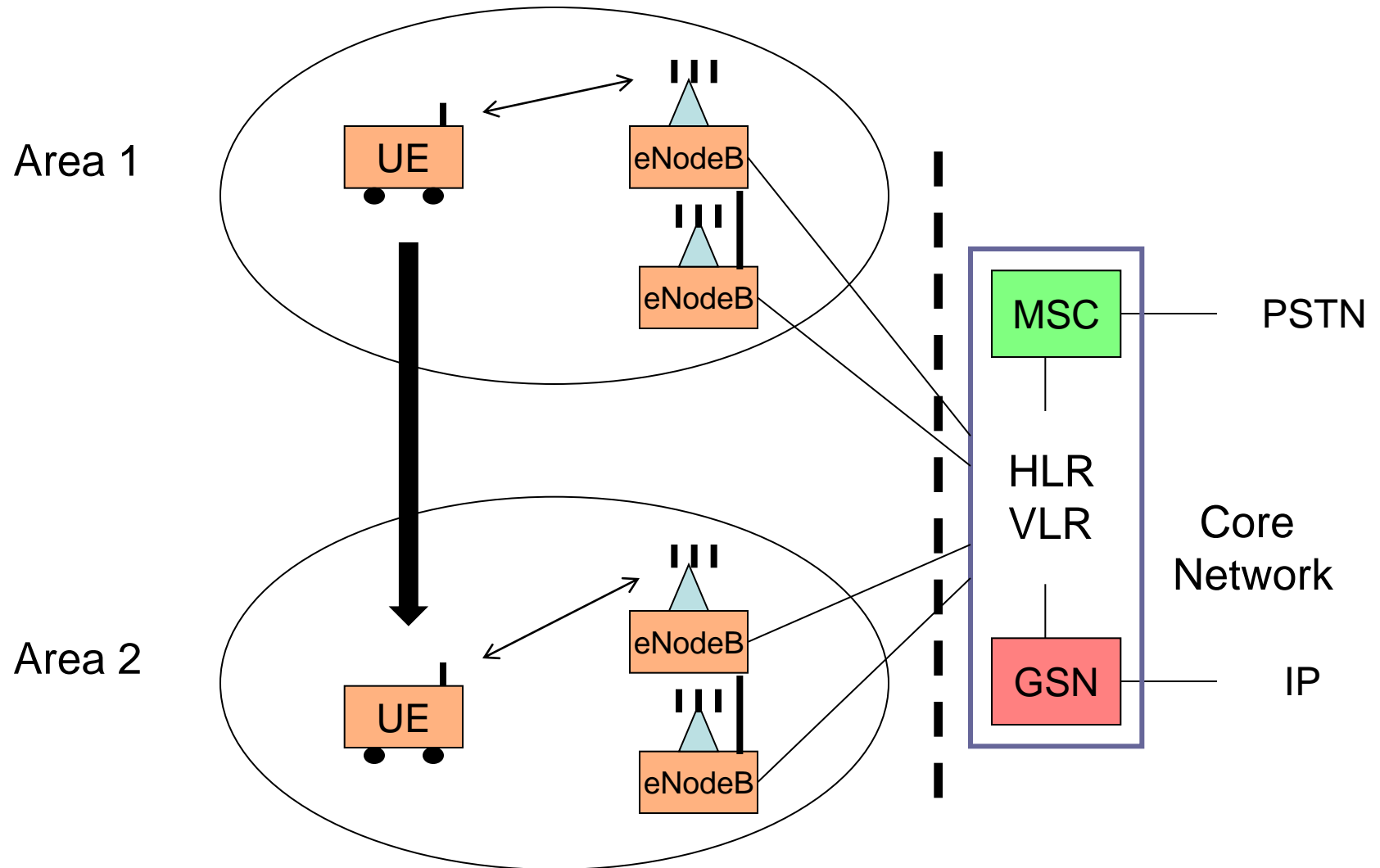
# CN Architecture: LTE



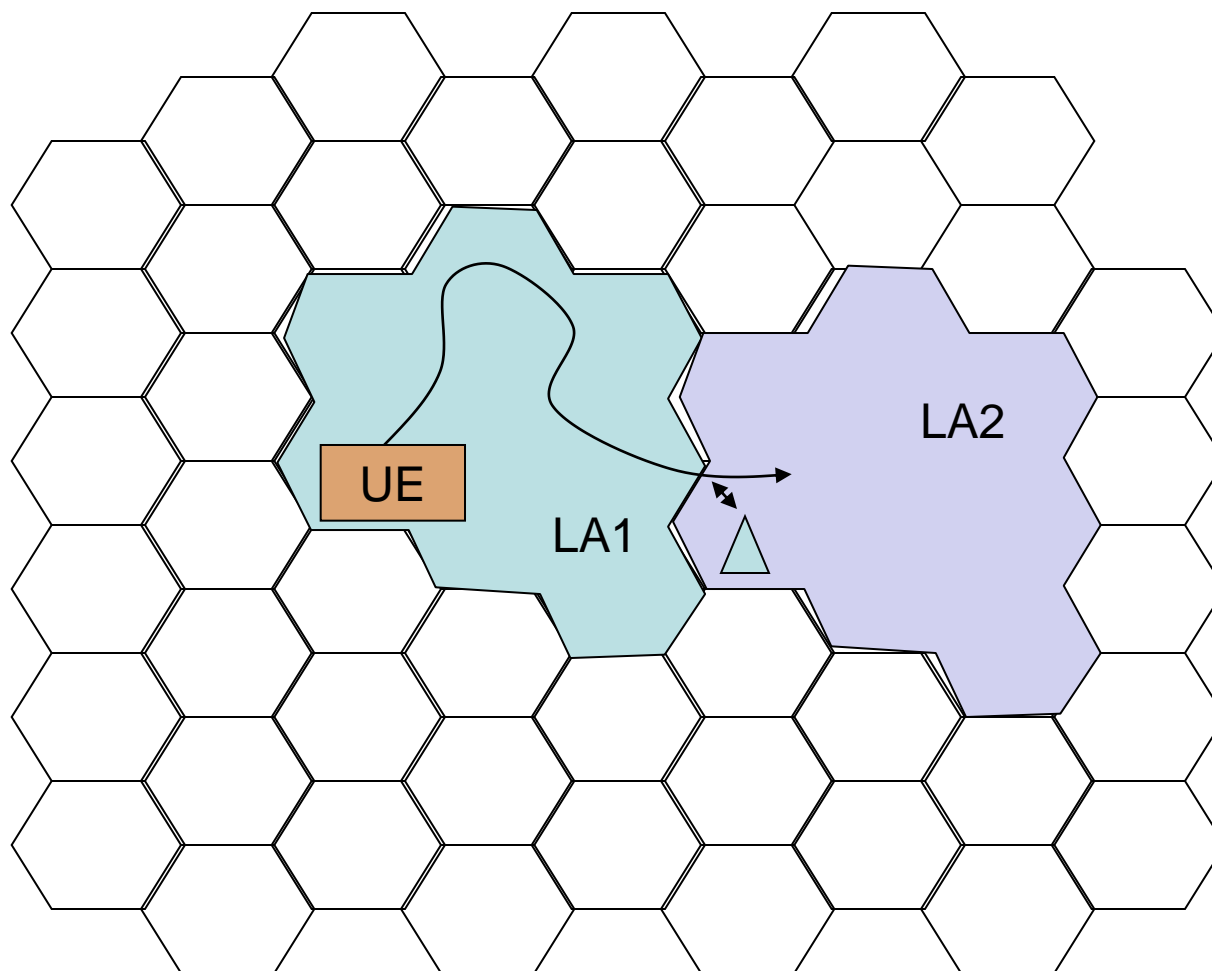
## 2. Mobility Management

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# Mobility Management (Macro Level): HLR, VLR



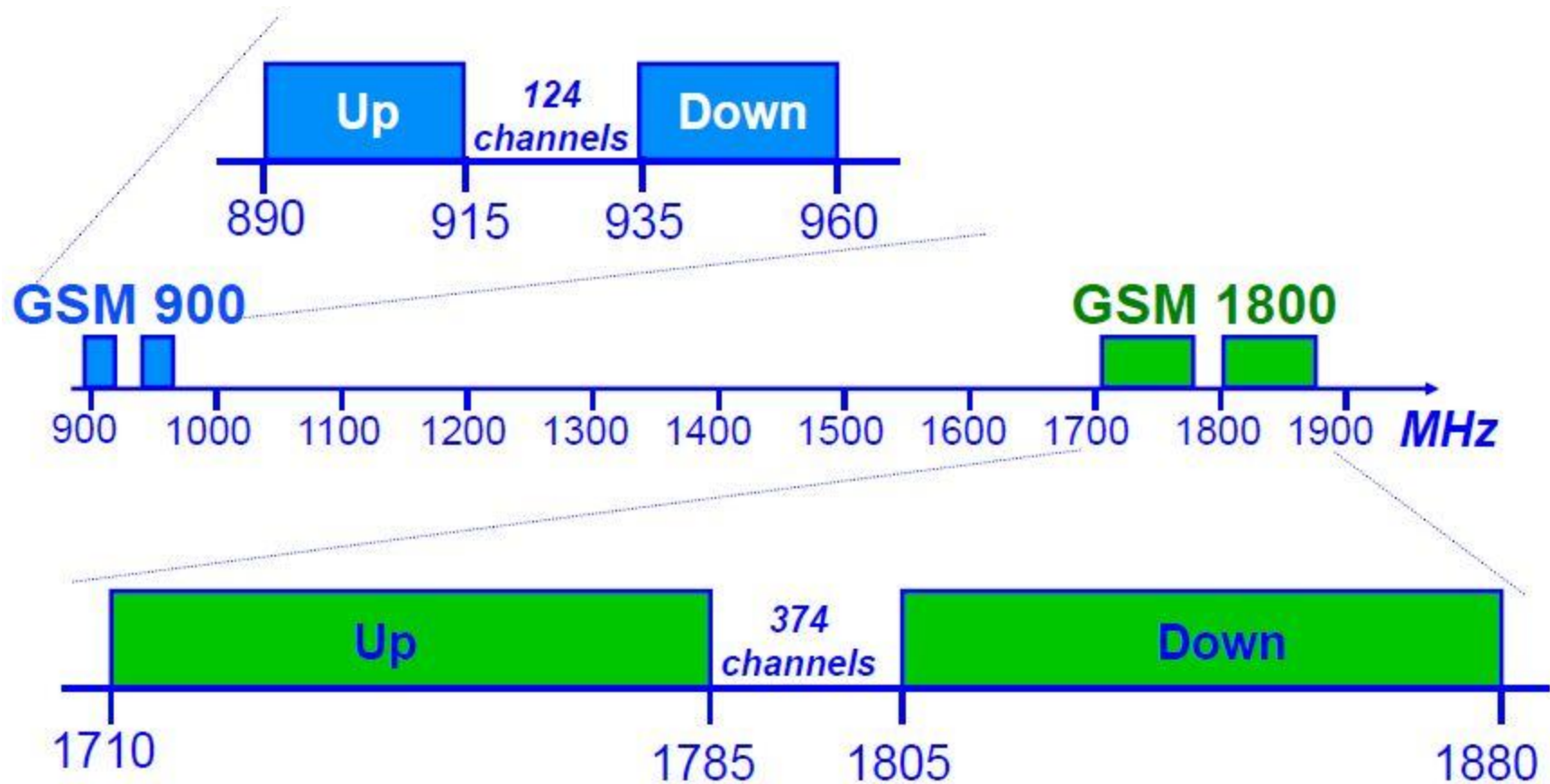
# Mobility Management (Micro Level): Location Areas



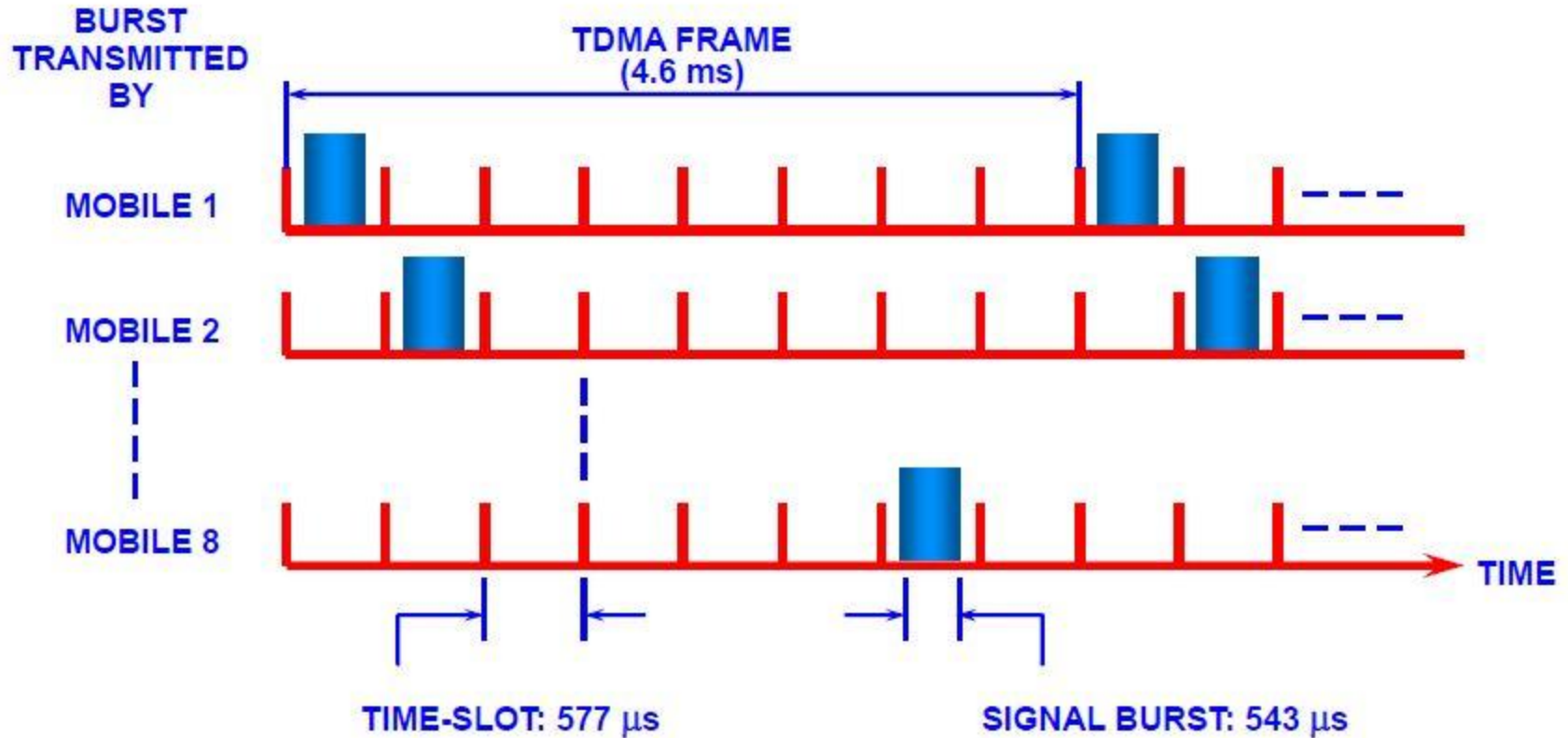
# 3. 2G

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# 2G (GSM)



# 2G (GSM)

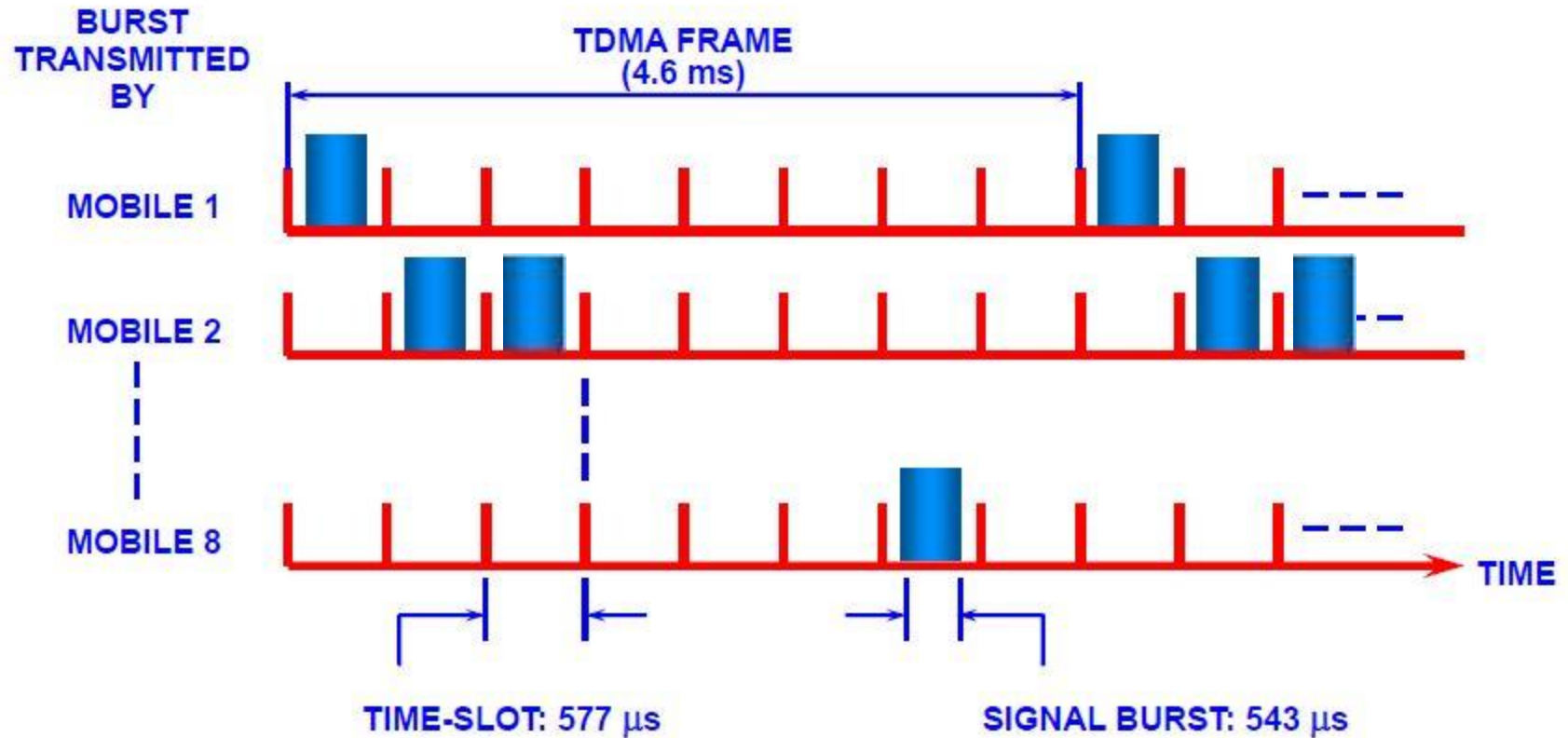


**F-TDMA:  $B_c = 200$  KHz;  $R_b = 271$  Kbit/s**

# 4. 2.5G

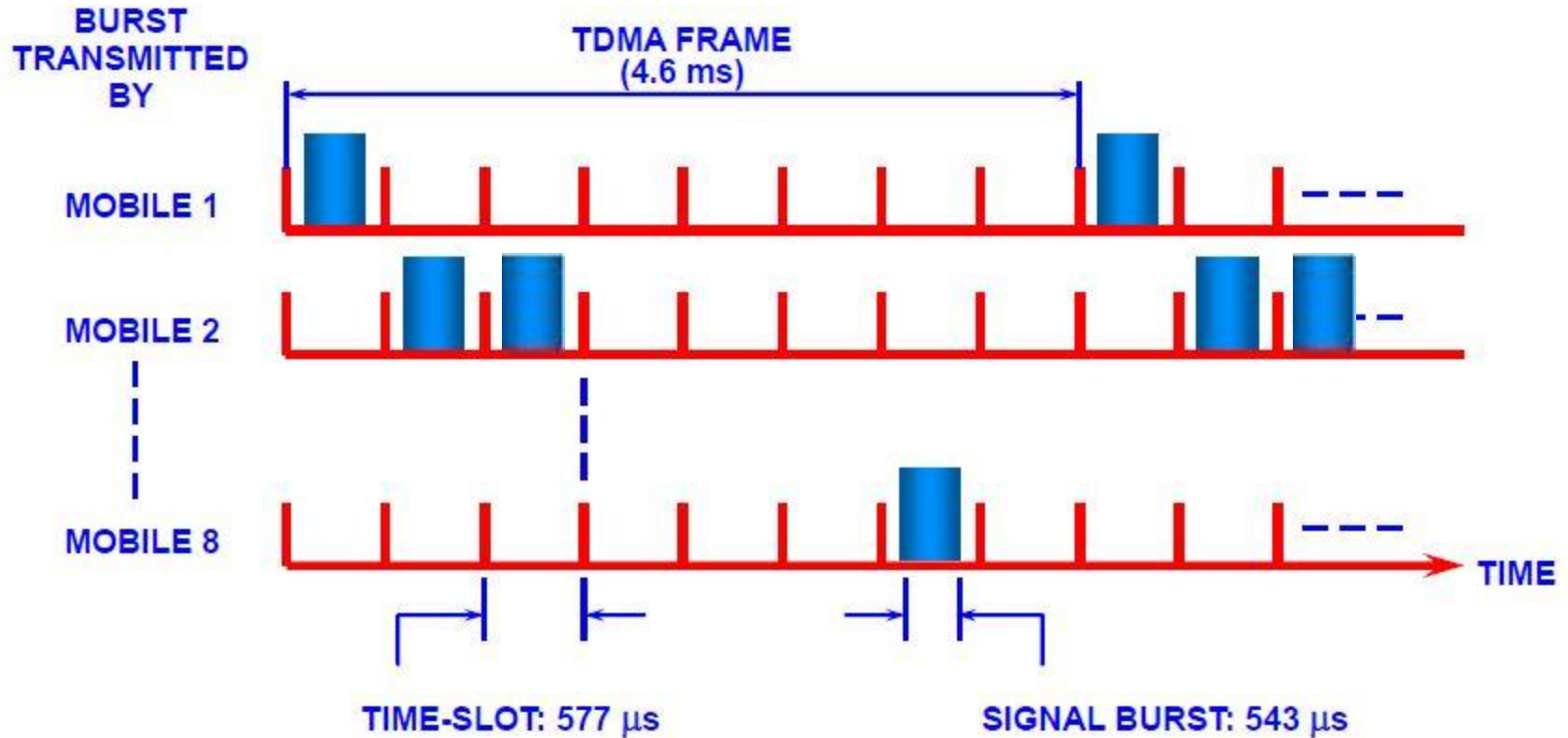
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# 2.5G (GPRS)



**F-TDMA:  $B_c = 200$  KHz;  $R_b = 271$  Kbit/s**

# 2.5G (EDGE)

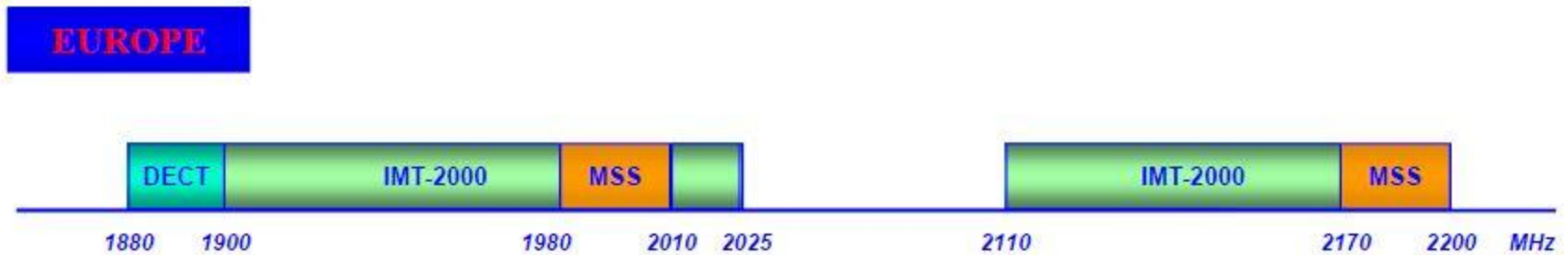
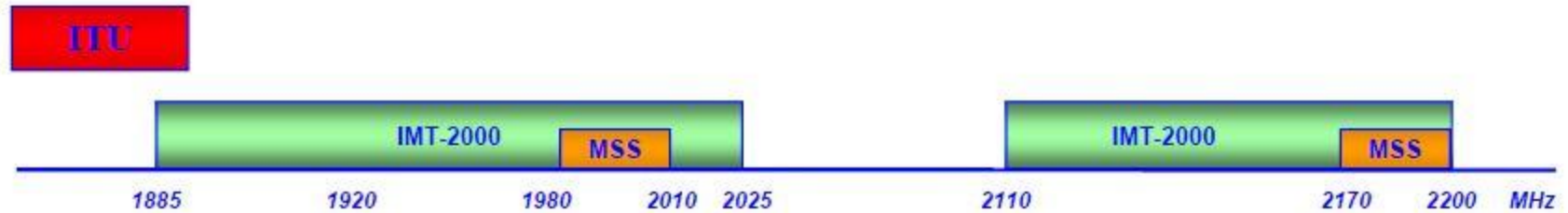


**F-TDMA:  $B_c = 200 \text{ KHz}$ ;  $R_b = 3 \times 271 \text{ Kbit/s}$**

# 5. 3G

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# 3G (UMTS)

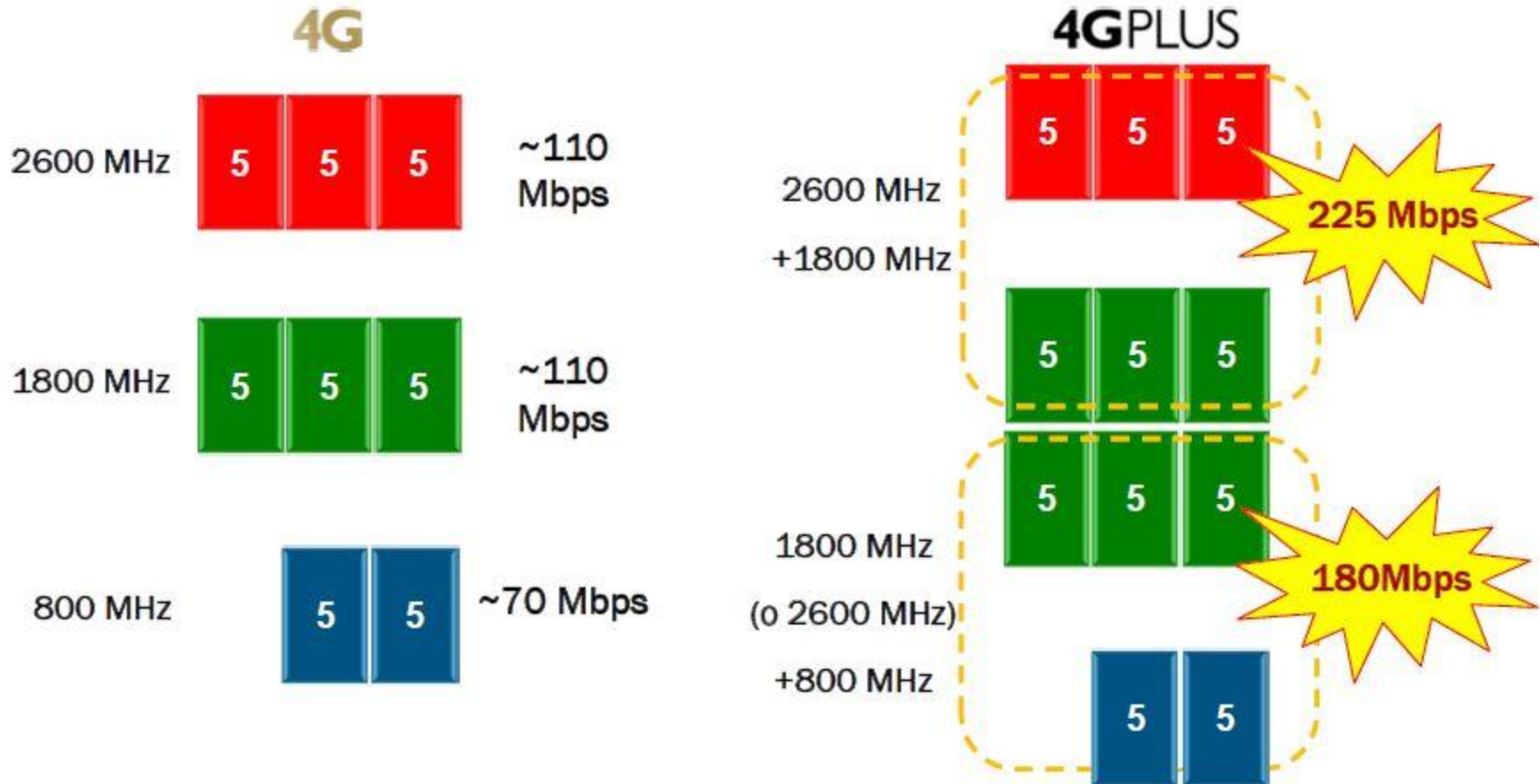


**F-T-CDMA:  $B_c = 5$  MHz;  $R_b =$  up to about 2 Mbit/s**

# 6. 4G

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# 4G (LTE-A)



**OF-TDMA:  $B_c = 5 \times N$  MHz;  $R_b =$  up to about 225 Mbit/s**

# 7. 5G

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# 5G



## Frequenze 5G Banda 700 MHz FDD

- 700 MHz blocco riservato (10 MHz) **Iliad** (676.472.792€)
- 700 MHz blocco generico (5 MHz) **Vodafone** (345.000.000€)
- 700 MHz blocco generico (5 MHz) **TIM** (340.100.000€)
- 700 MHz blocco generico (5 MHz) **TIM** (340.100.000€)
- 700 MHz blocco generico (5 MHz) **Vodafone** (338.236.396€)

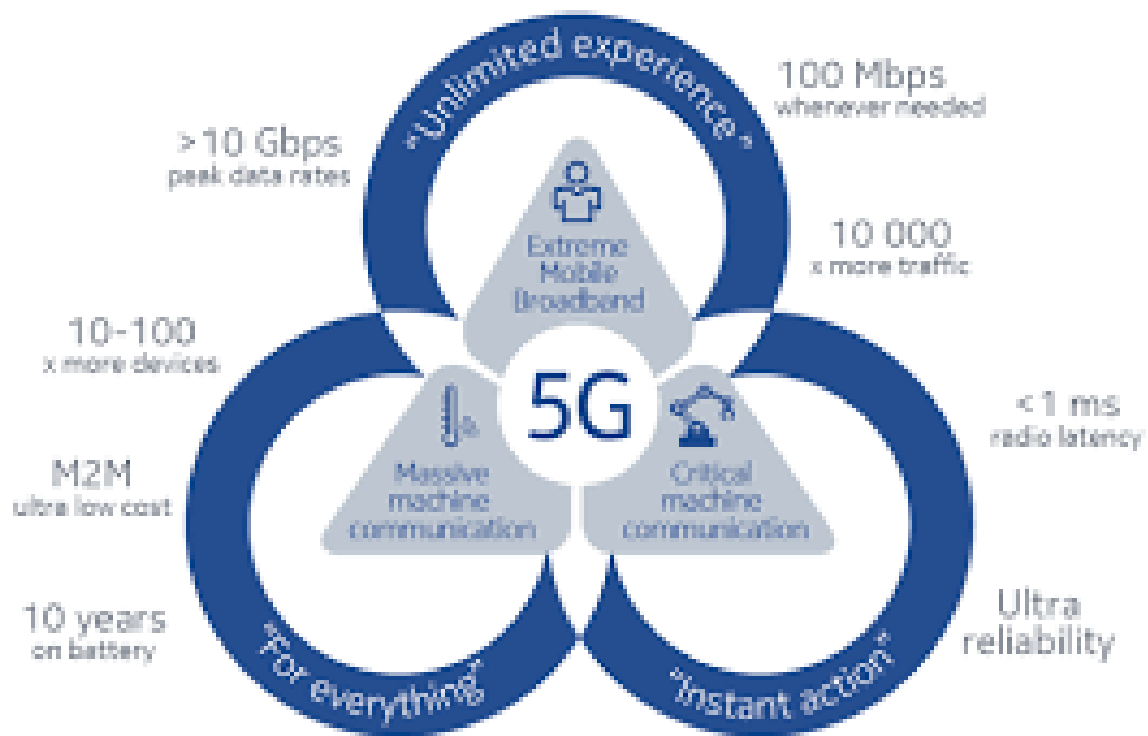
## Frequenze 5G Banda 3.700 MHz

- 3.700 MHz blocco specifico (80 MHz) **TIM** (1.694.000.000€)
- 3.700 MHz blocco generico (80 MHz) **Vodafone** (1.685.000.000€)
- 3.700 MHz blocco generico (20 MHz) **Wind Tre** (483.920.000€)
- 3.700 MHz blocco generico (20 MHz) **Iliad** (483.900.000€)

## Frequenze 5G Banda 26 GHz

- 26 GHz blocco generico **TIM** (33.020.000€)
- 26 GHz blocco generico **Iliad** (32.900.000€)
- 26 GHz blocco generico **Fastweb** (32.600.000€)
- 26 GHz blocco generico **Wind Tre** (32.586.535€)
- 26 GHz blocco generico **Vodafone** (32.586.535€)

# 5G



# 5G



- 1 Soft Air Interface**  
(Hybrid Numerology/Slot/Frame)
- 2 New Waveform**  
(F/W-OFDMA)
- 3 New Coding**  
(Polar Code, LDPC)
- 4 Ultra Low Latency**  
(Special Slot and Transmission Mechanism)
- 5 New Transmission Mode**  
(Grant Free)
- 6 New Access Scheme**  
(UCNC)
- 7 Enhanced MIMO**  
(Massive MIMO)
- 8 mmWave Transmission**  
(Beam-Centric UP/CP )



- 1 URLLC Enhancement
- 2 V2X**
- 3 MIMO Enhancement
- 4 IAB
- 5 NoMA
- 6 NTN
- 7 NR-U
- 8 Positioning

**Uses Cases for NR V2X**

**Requirements**



Vehicle Platooning



Cooperative Operation, Sensor sharing



Remote Driving



Advanced Driving

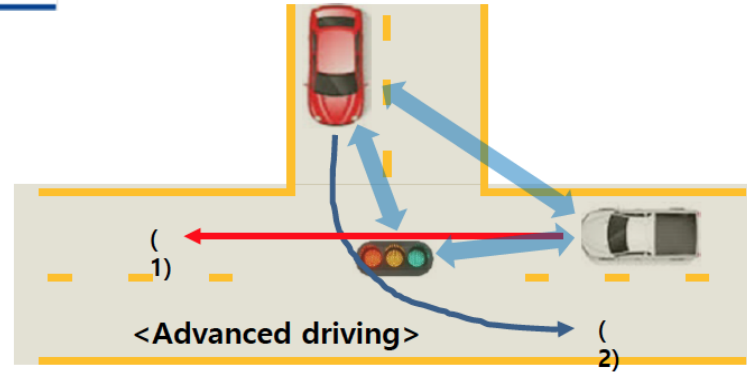
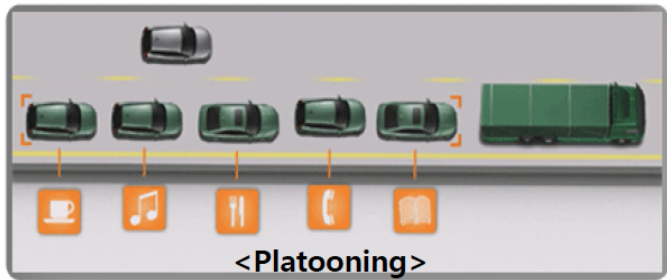
Use Cases	E2E latency (ms)	Reliability (%)	Data rate (Mbps)
Vehicle Platooning	10	99.99	65
Advanced Driving	3	99.999	53
Extended Sensors	3	99.999	1,000
Remote Driving	5	99.999	UL:25 DL:1

# 8. Application to Vehicular Comms.: 5G

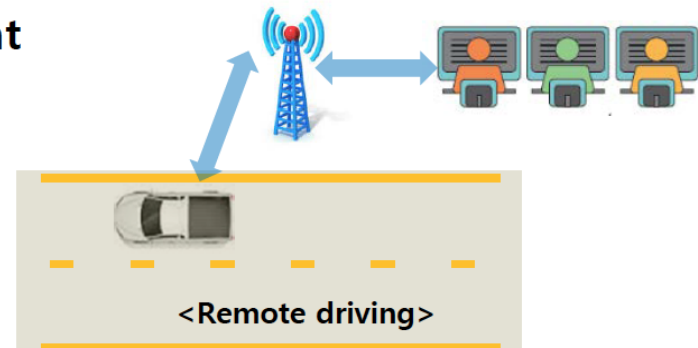
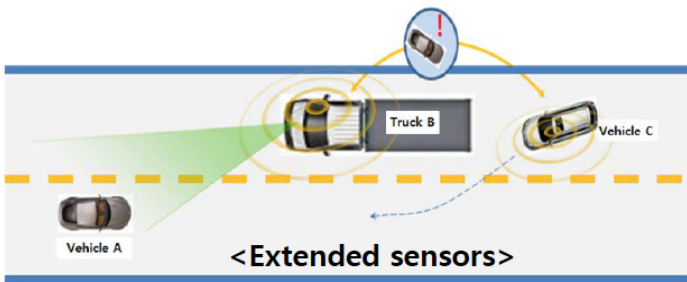
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# Application to Vehicular Comms.: 5G

## 5G Ex. Use cases



Use cases categories of eV2X use cases as per TR 22886  
Data rates beyond 25 Mb/s, scenario dependent



# Application to Vehicular Comms.: 5G

**3GPP TS 22.261 V16.4.0 (2018-06)**

*Technical Specification*

**3rd Generation Partnership Project;  
Technical Specification Group Services and System Aspects;  
Service requirements for the 5G system;  
Stage 1  
(Release 16)**



# Application to Vehicular Comms.: 5G

**Table A.1-1 Latency needs to support example use cases from vertical industries.**

Services/ Use cases	Automotive use cases	Transport, logistics, IoT use cases	Health and wellness, smart cities use cases	Media and entertainment
Description	Expand detectable range beyond on board sensor capability by sharing views or detected objects among traffic participants, coordinate trajectories among vehicles, sharing coarse driving intention, real-time remote operation of vehicles	Real-time sensing, reporting, feedback, control, remote, asset tracking, monitoring; context-aware services, recommendations at shopping mall, airport	Live video feed (4K, 8K, 3D for remote healthcare (consultation, monitoring) and assisted surgery, real-time commands to control medical devices for treatment (e.g., medication, surgery); remote monitoring, surveillance and guidance for citizens and law enforcement officers.	Media production services based on aggregation of various media feeds at servers; real-time peer-to-peer or server-client sharing of data (object information) for collaborative gaming, live streaming at live events
Latency	<p>For mid/long-term environment modelling (dynamic high-definition digital map update): Not critical (100 ms end-to-end)</p> <p>For short term environment modelling (sensor sharing): &lt;20 ms end-to-end</p> <p>For cooperation (coordinated control):</p> <ul style="list-style-type: none"> <li>- &lt;3 ms end-to-end for platooning,</li> <li>- &lt;10 ms end-to-end for cooperative manoeuvres.</li> <li>- &lt;100 ms end-to-end for coarse driving intention</li> </ul> <p>For remote vehicle operation: 10-30 ms end-to-end</p>	<p>For massive connectivity for time-critical sensing and feedback: &lt;30 ms end-to-end.</p> <p>For remote drone operation and cooperative farm machinery: 10-30 ms end-to-end</p> <p>Real-time control for discrete automation: ≤1 ms end-to-end</p>	<p>For real-time video/telepresence/augmented reality for remote healthcare and assisted surgery, for monitoring and guidance (smart cities): 100 ms end-to-end</p> <p>Real-time command and control for remote medication and surgery: 10-100 ms end-to-end</p> <p>For smart grid:</p> <ul style="list-style-type: none"> <li>- &lt;5 ms end-to-end for transmission/grid backbone,</li> <li>- &lt;50 ms end-to-end for distribution/grid backhaul,</li> </ul> <p>Time-critical sensing and feedback for smart cities: 30 ms end-to-end</p>	<p>For live streaming in crowded areas, services for media production, augmented reality for collaborative gaming etc.: 20 ms end-to-end</p>

# Application to Vehicular Comms.: 5G

**Table B.1-1 Positioning accuracy needs to support example use cases from vertical industries.**

Services/Use cases	Automotive use cases	Transport, logistics, IoT use cases	Health and wellness, smart cities use cases	Media and entertainment
Description	Uploading of sensed data to servers for dynamic digital map update; expand detectable range beyond on board sensor capability by sharing views or detected objects, coordinate trajectories among vehicles, sharing coarse driving intention, real-time remote operation of vehicles.	Sensing, reporting, feedback, control, related to predictive maintenance, asset tracking, monitoring; context-aware services, recommendations at shopping mall, airport, etc.	Remote healthcare and assisted surgery; real-time commands to control medical devices; connectivity for sensors, wearable devices and other medical devices; remote monitoring, surveillance and guidance for citizens and law enforcement officers.	Media production services based on aggregation of various media feeds at servers; real-time peer-to-peer or server-client sharing of data (object information) for collaborative gaming
Positioning accuracy	<p>For mid/long-term environment modelling (dynamic high-definition digital map update):</p> <ul style="list-style-type: none"> <li>- &lt;30 cm relative to other map objects</li> </ul> <p>For short term environment modelling (sensor sharing), for cooperation (coordinated control), remote vehicle operation:</p> <ul style="list-style-type: none"> <li>- &lt;30 cm (can be &lt;10 cm in certain cases, e.g., parking, pedestrian);</li> <li>- &lt;1 m for sharing coarse driving intention (coordinated control), e.g., changing lanes, merging at highway.</li> </ul> <p>Indoor positioning also needed, e.g., tunnels, parking.</p>	<p>For massive connectivity for non-time-critical sensing and time-critical sensing and feedback:</p> <ul style="list-style-type: none"> <li>- 30 cm – 1 m sufficient for many applications</li> <li>- &lt;30 cm for applications that require exact localization (e.g., tracking specific objects in a warehouse).</li> </ul> <p>Indoor positioning also needed, e.g., warehouse, airport, train station.</p>	<p>For remote healthcare and assisted surgery; for real-time monitoring for smart cities:</p> <ul style="list-style-type: none"> <li>1-10 m, e.g., remote assisted surgery, wellness monitoring; remote monitoring (surveillance) and guidance for citizens.</li> </ul> <p>Indoor positioning also needed, e.g., house, medical centre</p>	<p>For media production and collaborative gaming:</p> <ul style="list-style-type: none"> <li>30 cm – 1 m, e.g., location data that could help media production process, create new gaming applications utilising location information</li> </ul> <p>Indoor positioning may also be useful</p>