5G/B5G URLLC Services and New Opportunities

Dec. 11, 2017

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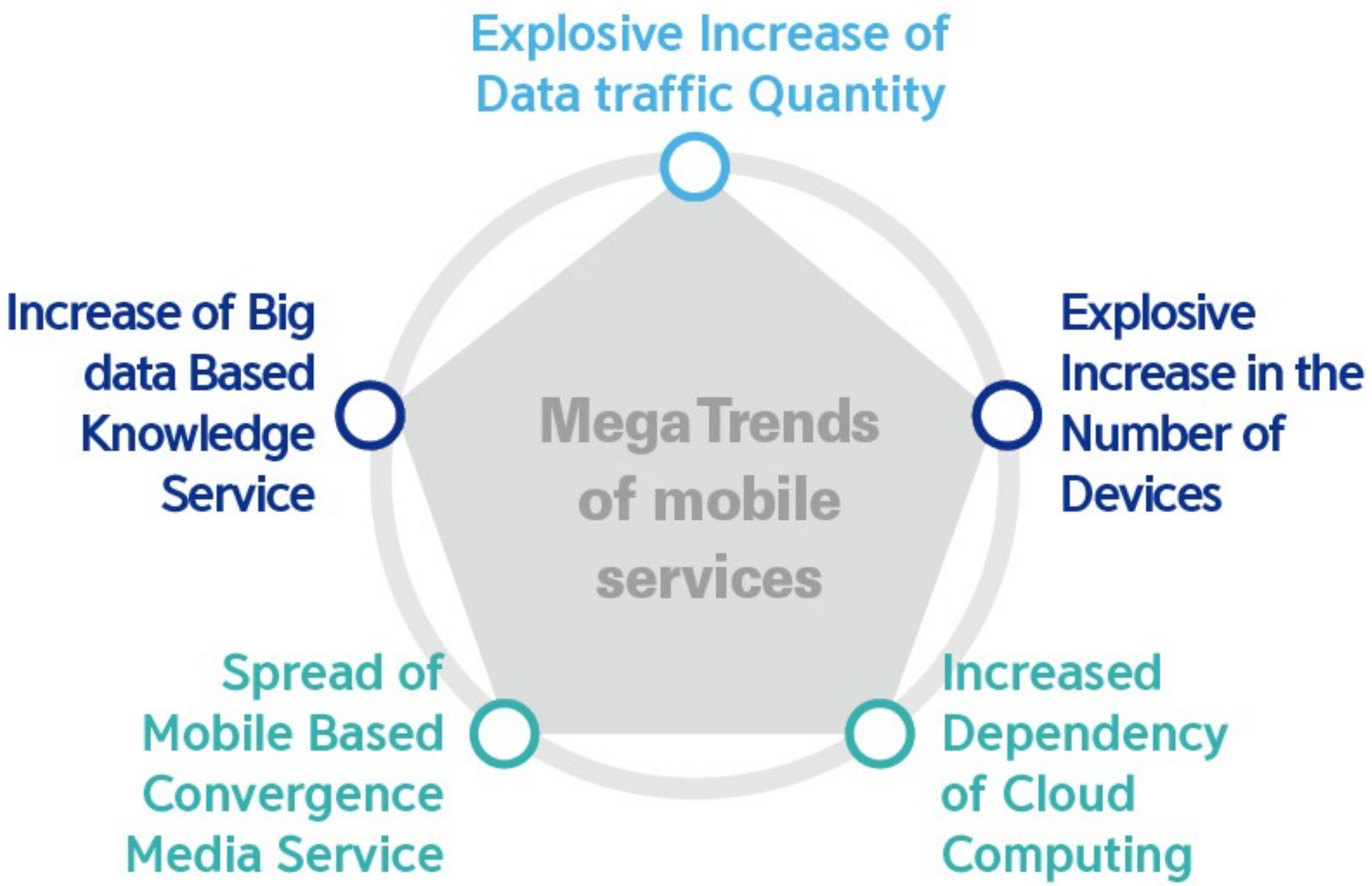
Outline

1. Introduction
2. Service Classification
3. URLLC Use-Cases and Requirements
4. URLLC Challenges and Conclusions

Introduction

Mobile Service Mega Trends

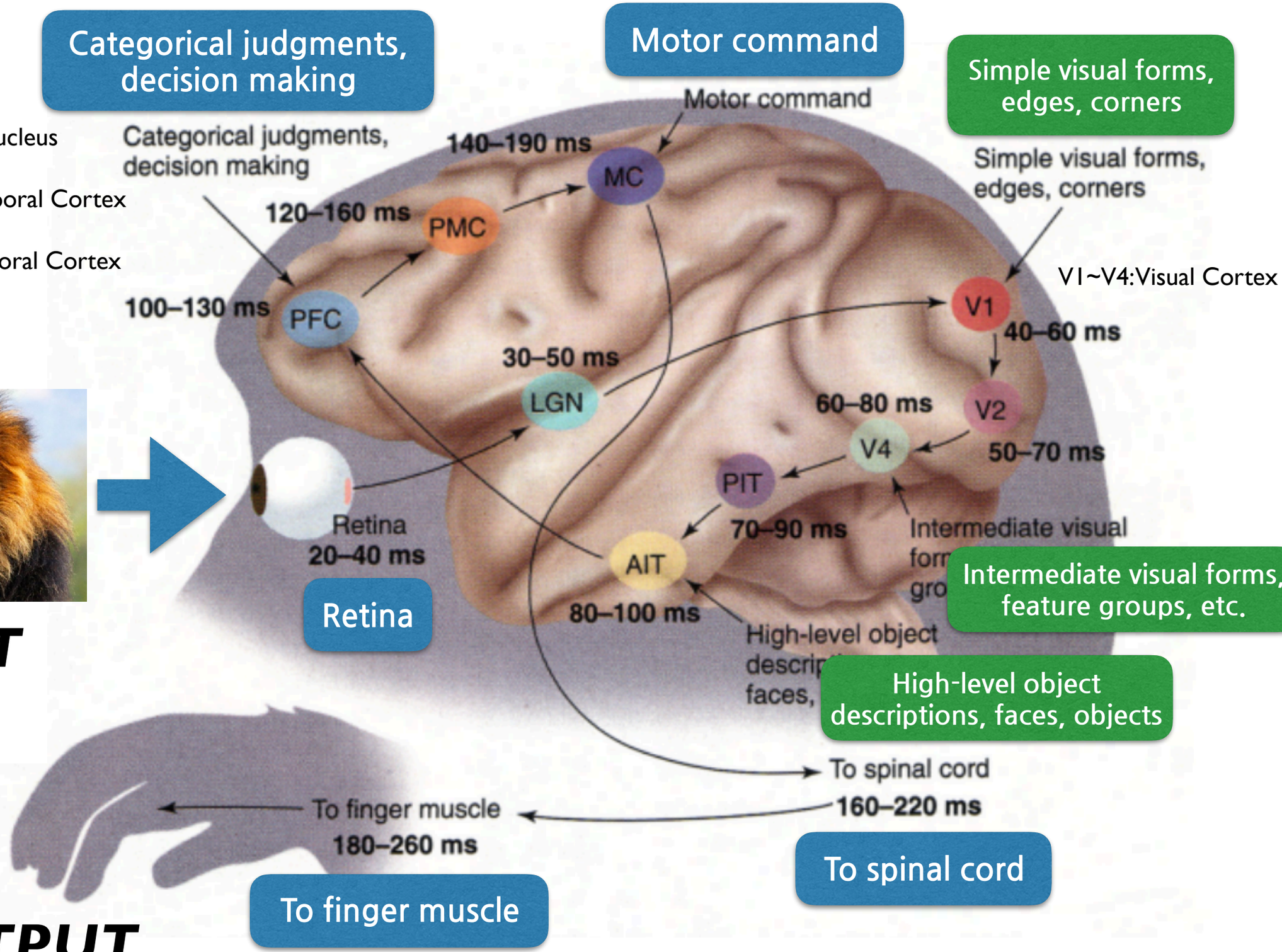


→ Five Golden Opportunities !!

From INPUT to OUTPUT

PFC: PreFrontal Cortex
(전전두피질)
PMC: PreMotor Cortex
(전운동피질)
MC: Motor Cortex
(운동피질)
LGN: Lateral Geniculate Nucleus
(외측슬상체)
PIT: Posterior Inferior Temporal Cortex
(Posterior 하측두피질)
AIT: Anterior Inferior Temporal Cortex
(Anterior 하측두피질)

INPUT



OUTPUT

180~260ms

(Source: Simon J.Thorpe'01)

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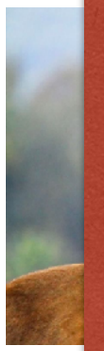
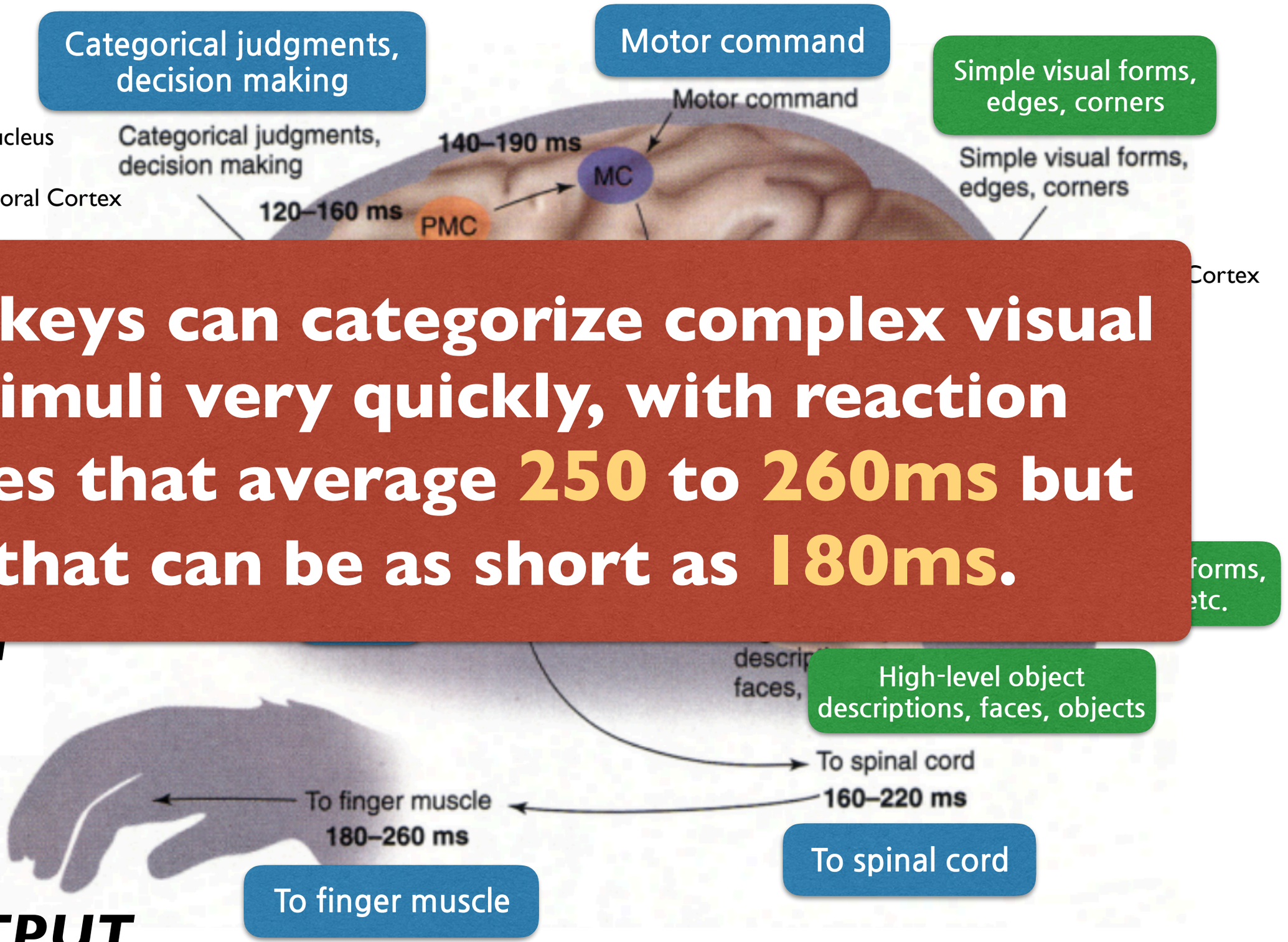
(Anterior



Monkeys can categorize complex visual stimuli very quickly, with reaction times that average 250 to 260ms but that can be as short as 180ms.



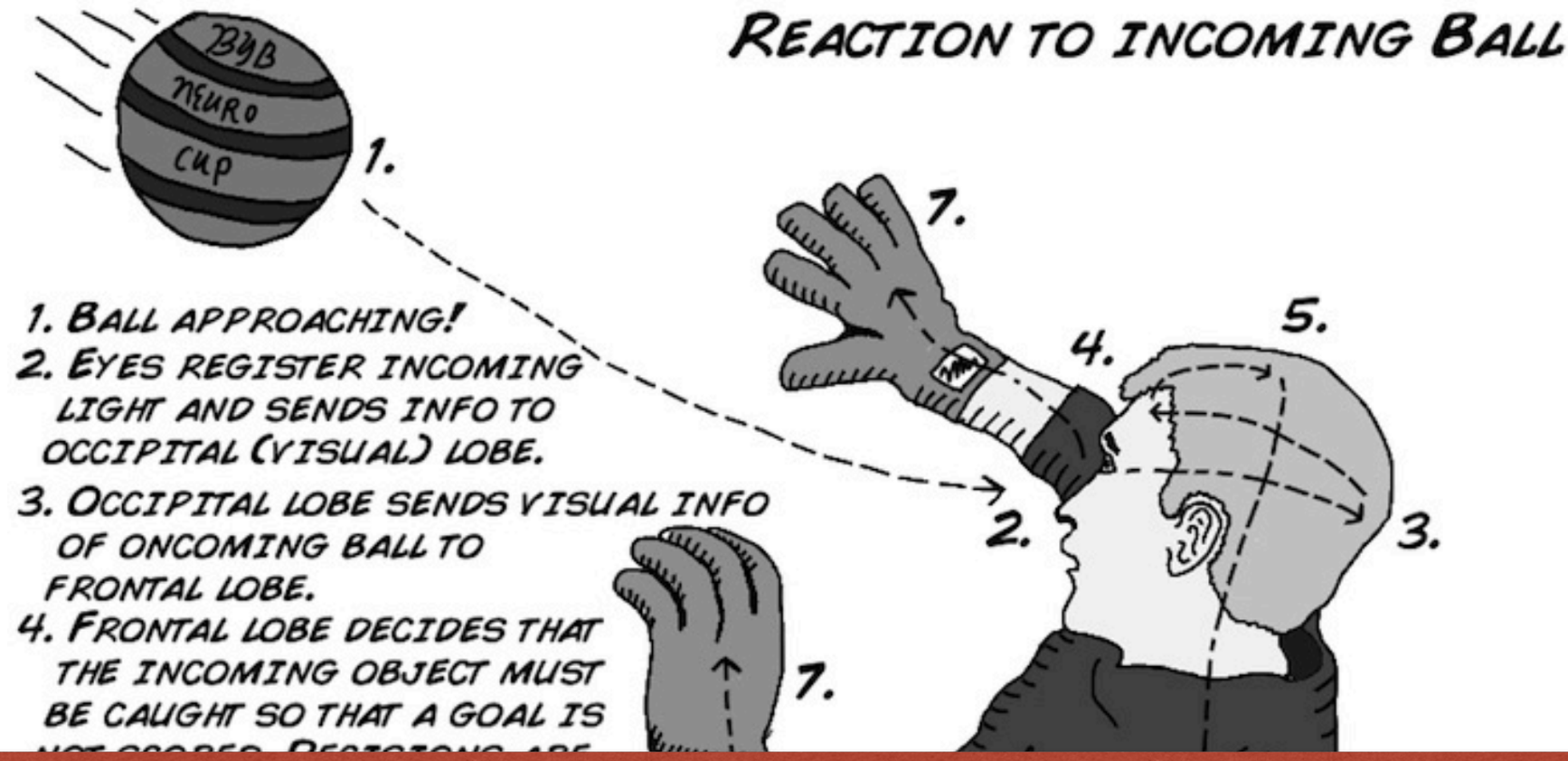
INPUT

OUTPUT

180~260ms

(Source: Simon J. Thorpe'01)

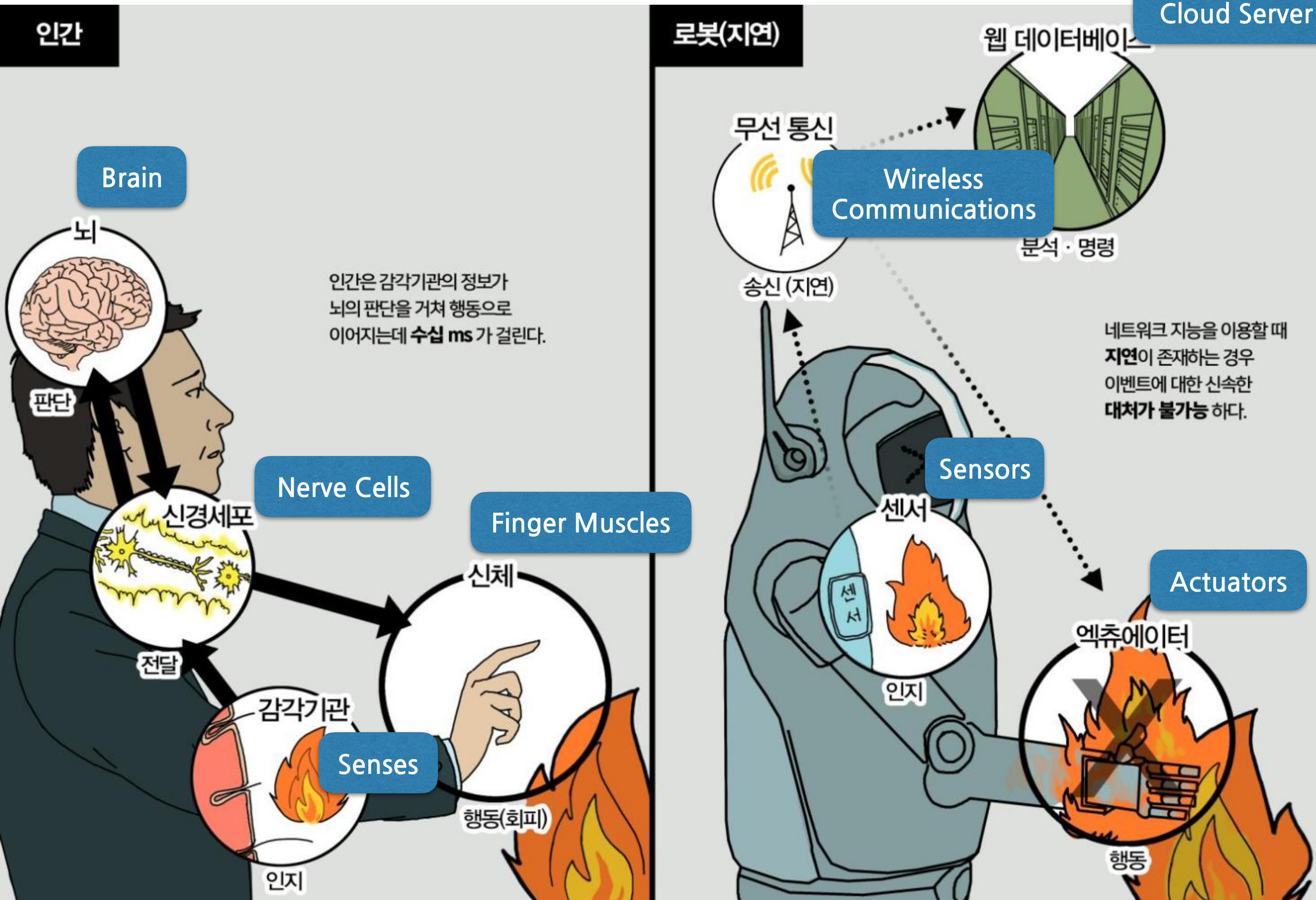
How Fast Your Brain Reacts to Stimuli



The average reaction time for humans is 250ms to a visual stimulus, 170ms for an audio stimulus, and 150ms for a touch stimulus.

(Source: Backyard Brains)

Human Reaction Mechanism Modeling



Human Reaction Mechanism Modeling

인간

Brain

뇌

판단

Nerve Cells

신경세포

전달

Finger Muscles

신체

감각기관

Senses

행동(회피)

인지

인간은 감각기관의 정보가
뇌의 판단을 거쳐 행동으로
이어지는데 **수십 ms** 가 걸린다.

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로봇(초저지연)

Cloud Server

웹 데이터베이스

무선·통신

Wireless Communications

분석 · 명령

송수신 (저지연)

네트워크 지능을 이용할 때
초저지연이 가능한 경우
사람 수준의 반사행동이
가능해 진다.

Sensors

센서

센서

인지

Actuators

엑츄에이터

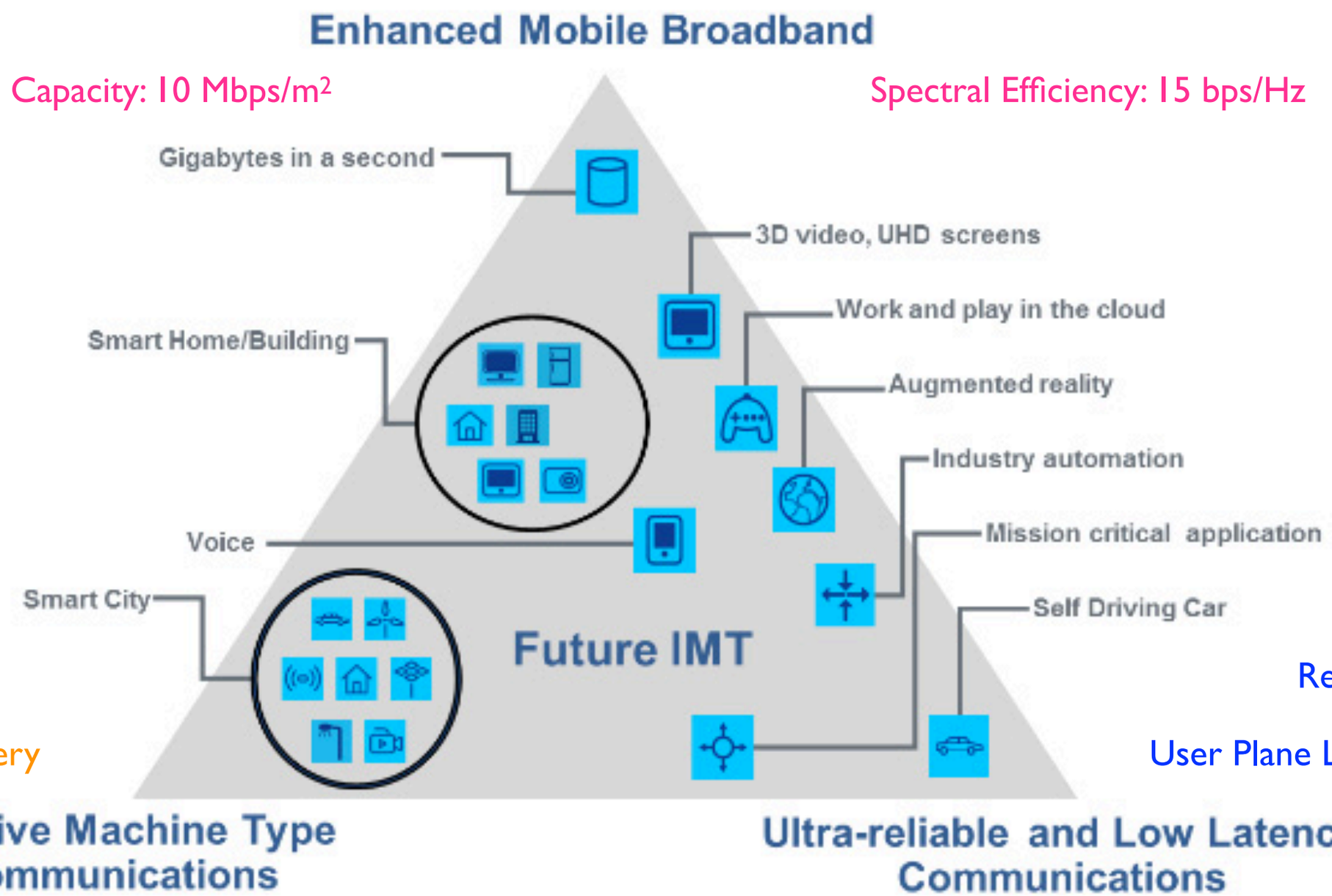
행동(회피)

Service Classification

Service Classification

Peak Data Rate: 10 Gbps

Average Data Rate: 50 Mbps



Area Traffic Capacity: 10 Mbps/m^2

Spectral Efficiency: 15 bps/Hz

Reliability: 10^{-5}

10 years on battery

User Plane Latency: 1ms

Connection Density: 1,000,000 devices/km^2

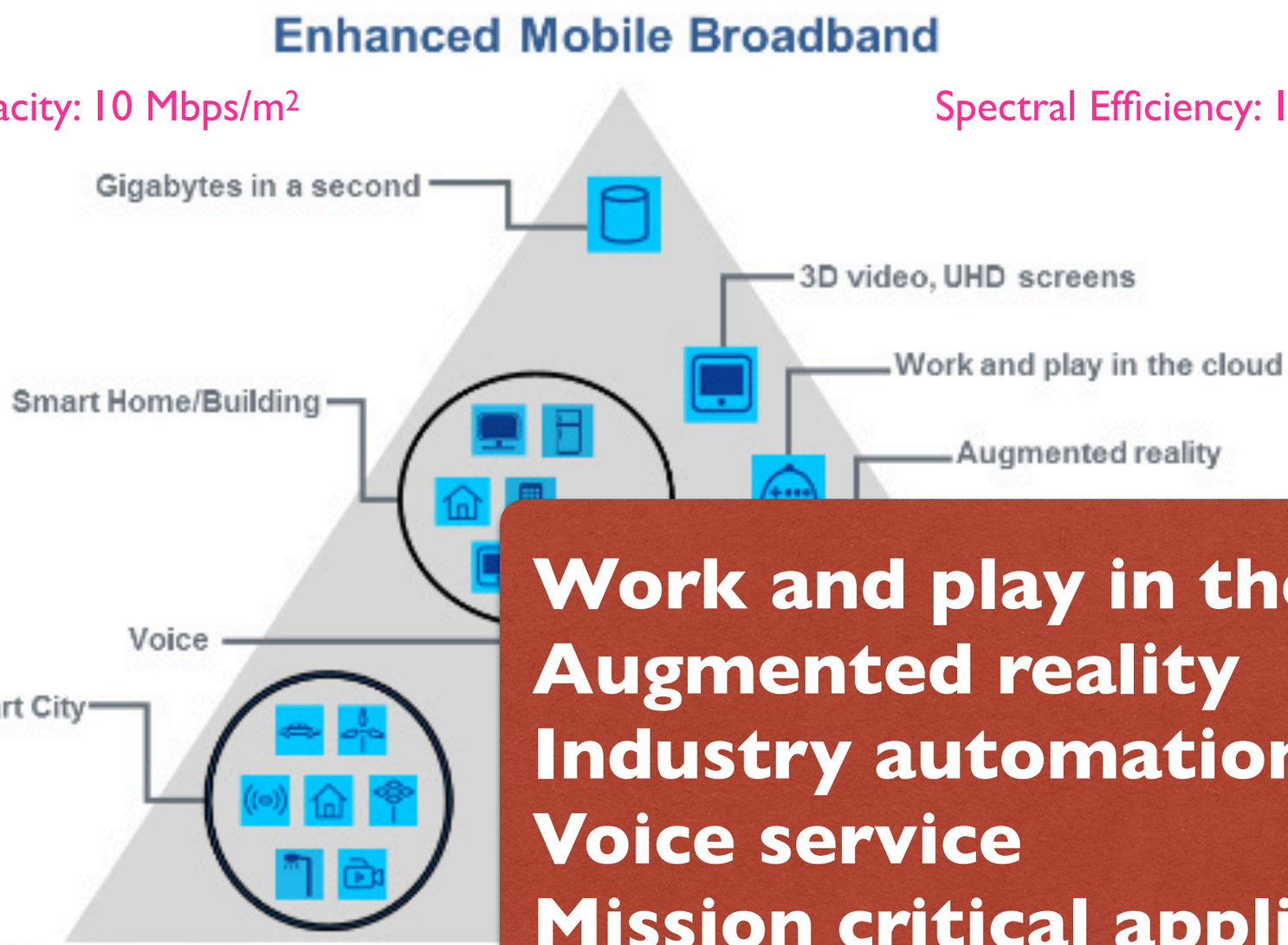
Control Plane Latency: 10ms

(Source: ITU-R)

Service Classification

Peak Data Rate: 10 Gbps

Average Data Rate: 50 Mbps



Area Traffic Capacity: 10 Mbps/m²

Spectral Efficiency: 15 bps/Hz

Work and play in the cloud
Augmented reality
Industry automation
Voice service
Mission critical application
Self driving car

10 years on battery

10^{-5}

1ms

Connection Density: 1,000,000 devices/km²

Control Plane Latency: 10ms

(Source: ITU-R)

Service Classification

Intelligent

지능형 5G 서비스(나를 알아주는...)

Intelligence

Immersive

몰입형 5G 서비스

(내가 느끼는...)

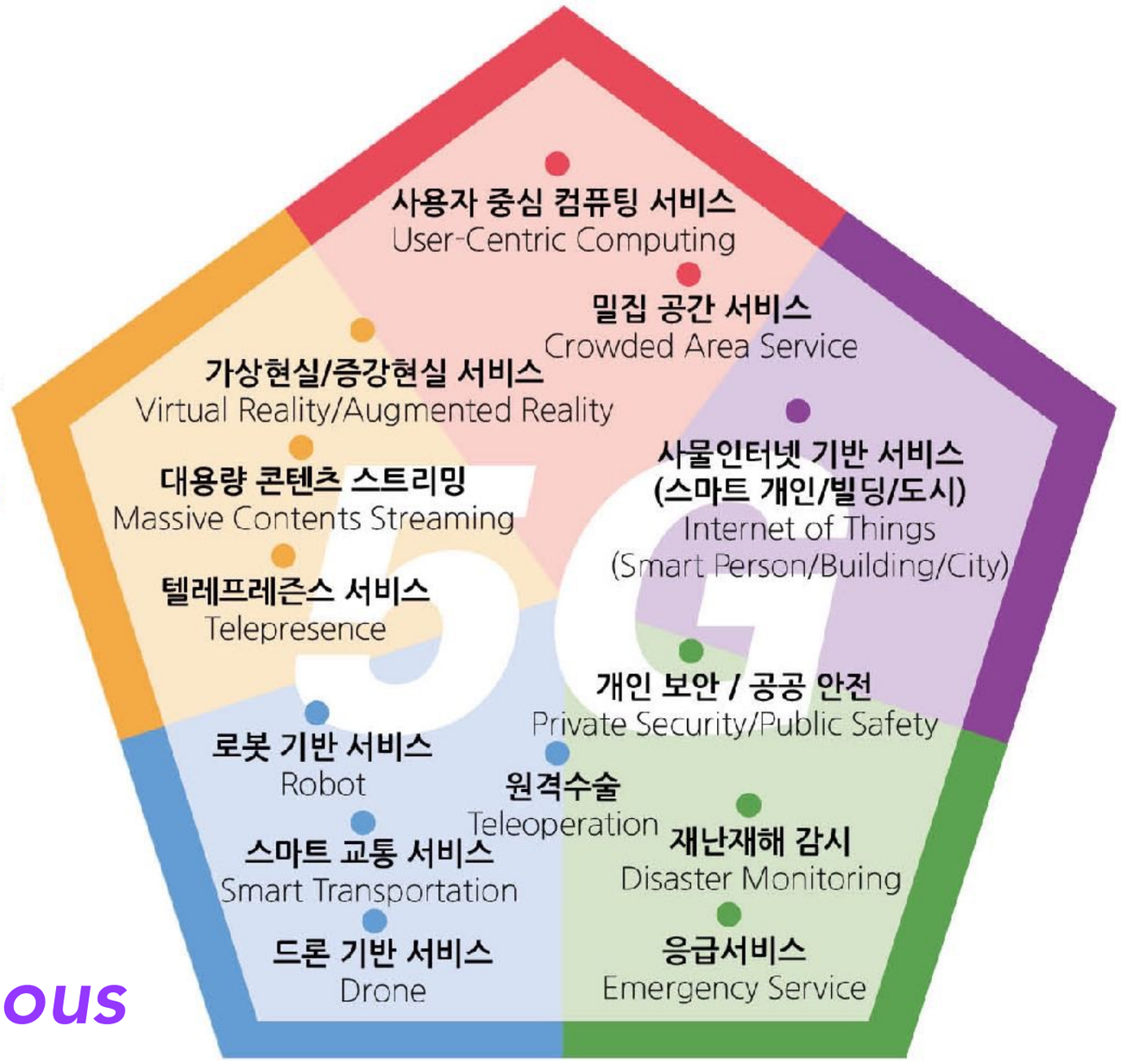
Immersiveness

Omnipresent

편재형 5G 서비스

(나를 둘러싼...)

Omnipresence



Autonomous

Public

자율형 5G 서비스(나를 도와주는...)

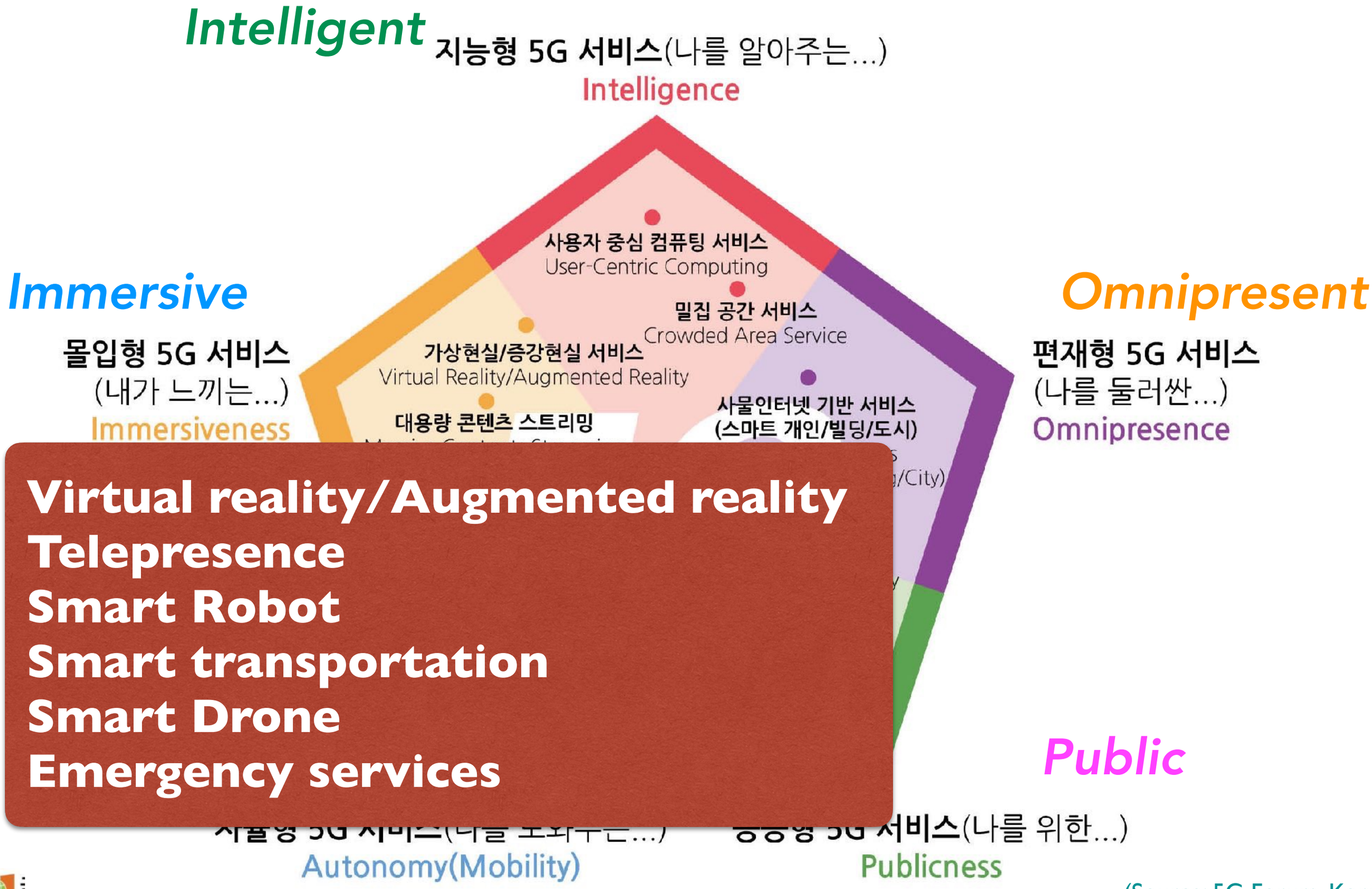
Autonomy(Mobility)

공공형 5G 서비스(나를 위한...)

Publicness

(Source: 5G Forum, Korea)

Service Classification

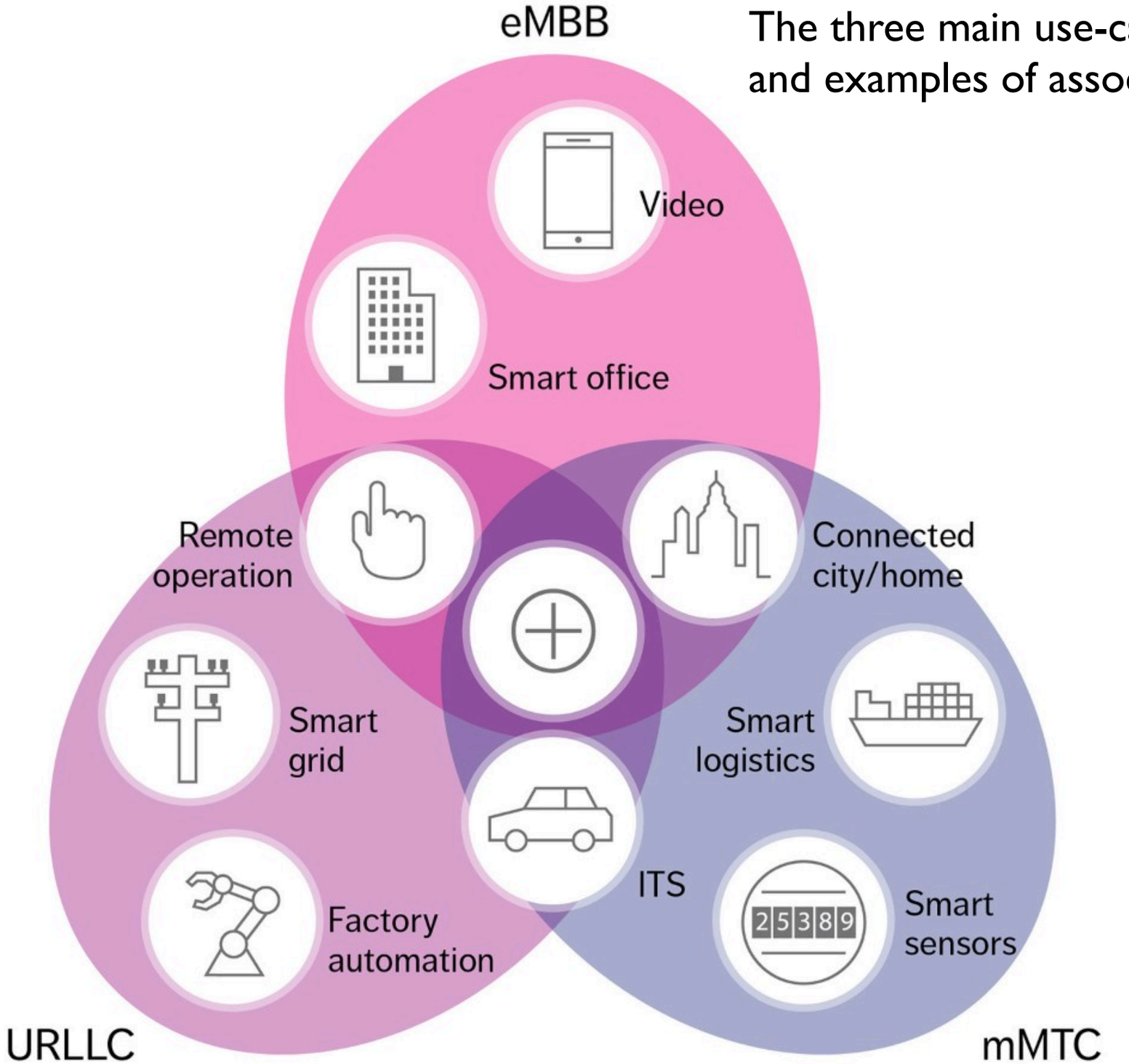


Virtual reality/Augmented reality
Telepresence
Smart Robot
Smart transportation
Smart Drone
Emergency services

(Source: 5G Forum, Korea)

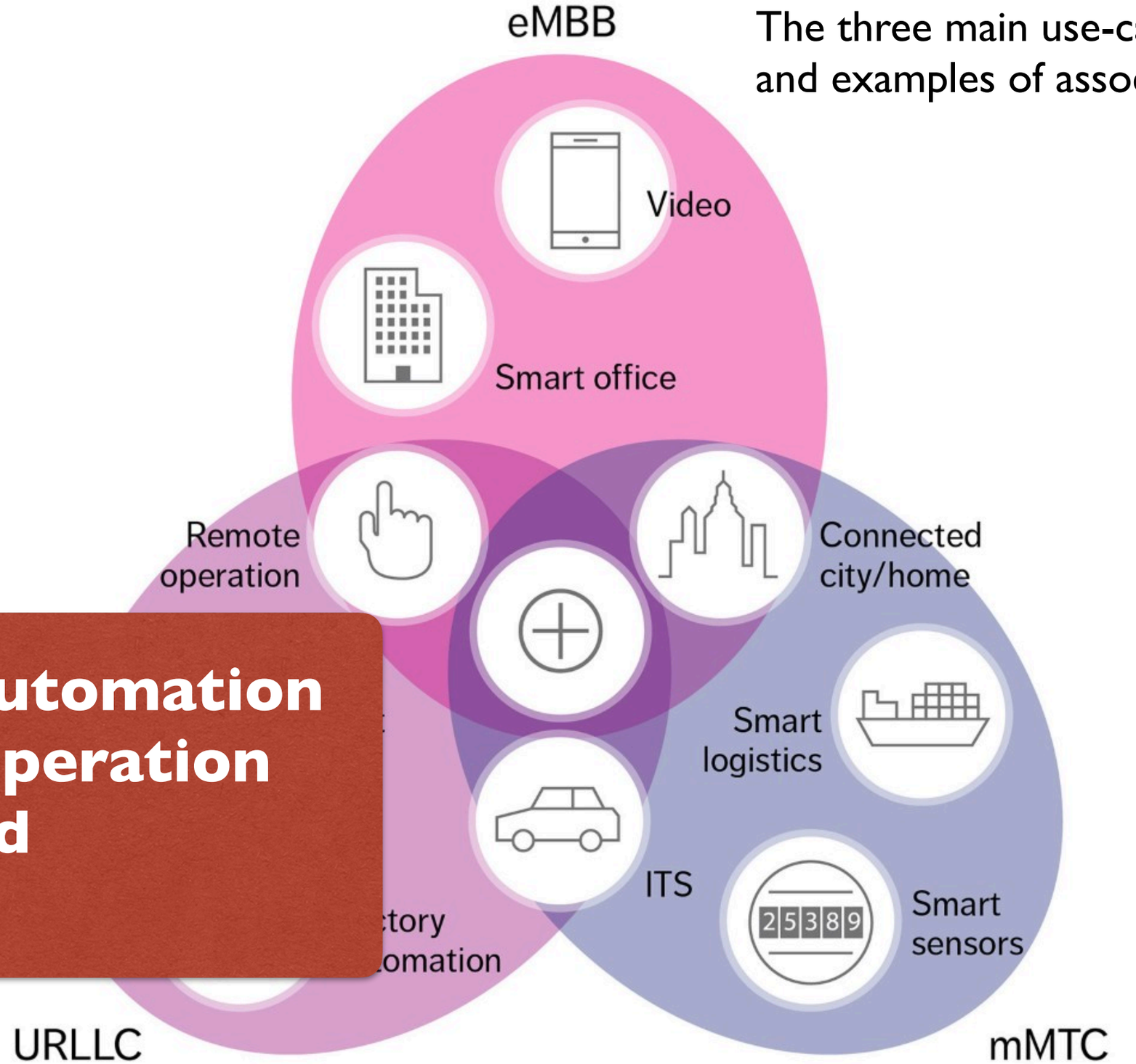
Service Classification

The three main use-cases
and examples of associated applications



(Source: Ericsson)

Service Classification

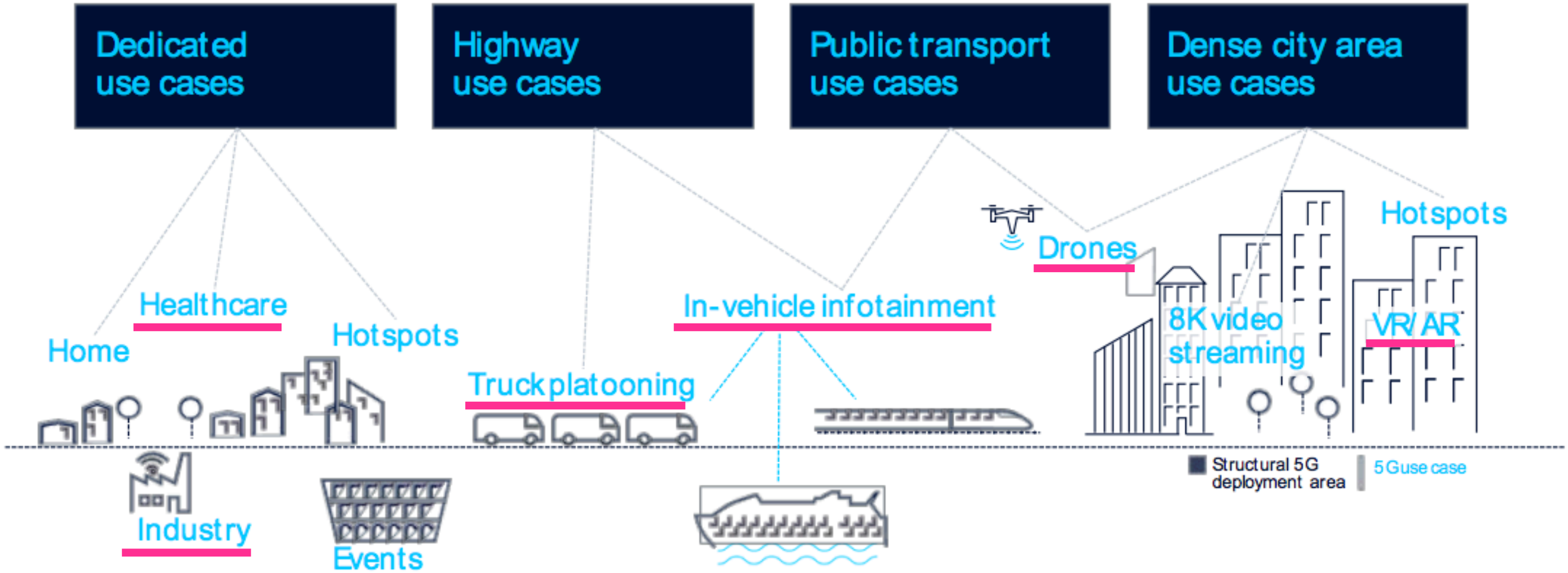


The three main use-cases
and examples of associated applications

Factory automation
Remote operation
Smart grid
ITS

(Source: Ericsson)

Service Classification

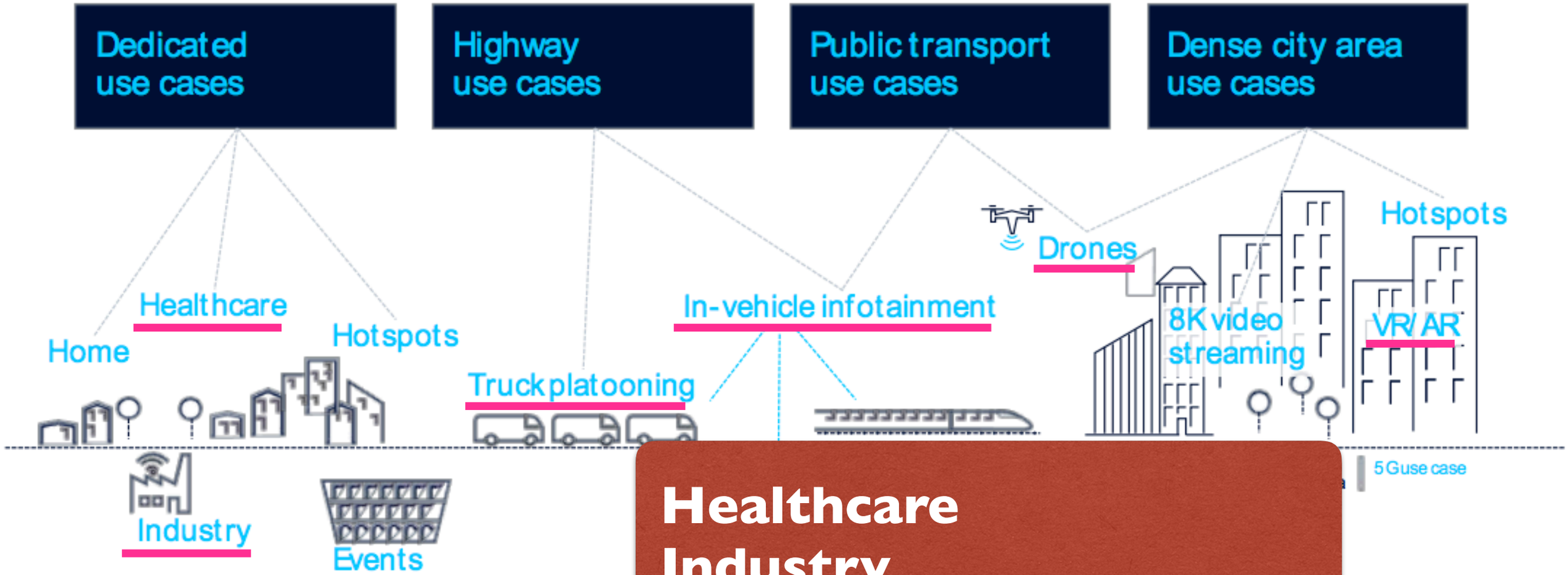


Healthcare
Industry
Truck platooning

In-vehicle infotainment
Drones
VR/AR

(Source: Nokia)

Service Classification



Healthcare
Industry
Truck platooning
In-vehicle infotainment
Drones
VR/AR

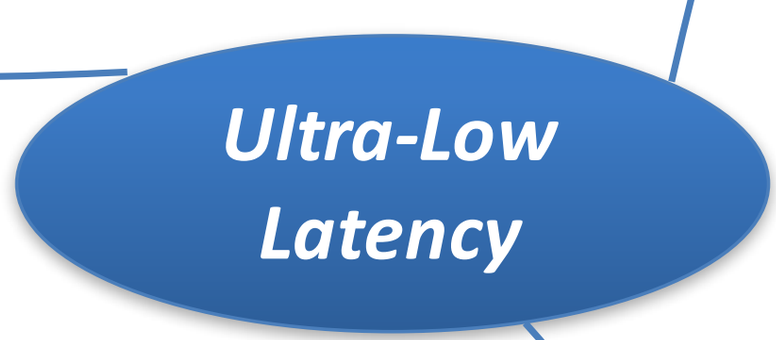
(Source: Nokia)

Low-Latency Service Classification

- Telepresence
- Ultra-Fast Touch Response
- Realistic gaming
- Mobile virtual office
- Virtual Reality with Tactile Feedback

Reality via Networks: ***Enhanced Delay***

Enhanced



Control via Networks: ***Absolute Delay***

Absolute

- Traffic Control
- Traffic Safety
- Teleprotection
- Platooning of Vehicles
- Intersection
- SCPR
- Personal Blackbox

Summary

Enhanced - Reality
Absolute - Control
Relative - Competition

Competition via Networks: ***Relative Delay***

- Ultra-Low Latency Gaming
- Algorithmic Trading
- Course Registration

Relative

URLLC Use-Cases and Requirements

URLLC Use-Cases and Requirements

Industry Vertical		Application
Healthcare Industry		Remote robotic surgery with haptic feedback Remote diagnosis with haptic feedback Emergency response in ambulance
Transport Industry		Driver assistance applications Enhanced safety Self-driving cars Traffic management
Entertainment Industry		Immersive AR/VR services Online gaming
Manufacturing Industry		Motion control Remote control with AR applications

(Source: M. Dohler'17)

URLLC Use Cases

- **Remote healthcare and medical intervention (1/2)**
  - In past tele-surgery trials with ***no use of haptic feedback***, mentors can compensate delays up to 700ms in less interactive scenarios, while in more interactive mentoring scenarios a shorter delay of up to 250ms is required.
  - In the context of tele-surgery, real experiments have determined that the maximum tolerable delay is 150ms. (Source: P. Dasgupta'03)

(Source: Tele-Visual Infolink)

URLLC Use Cases

- **Remote healthcare and medical intervention (2/2)**
  - Since there's no haptic feedback included in the previous delay requirement, the reported delays here are all just one way delay.
  - However, ***haptic feedback*** in remote surgery and diagnosis scenarios can increase the accuracy in detection of nodules.
  - Adding the haptic feedback, however, tighten the requirements[결절] on latency, since kinesthetic devices work in closed control loops and the two ends (action and reaction) should operate synchronously with each other.
  - ***So, tele-surgery in the presence of haptic feedback requires end-to-end round trip times (RTTs) of lower than 10ms.***

(Source: M. Spong'89 & M. Spong'92)

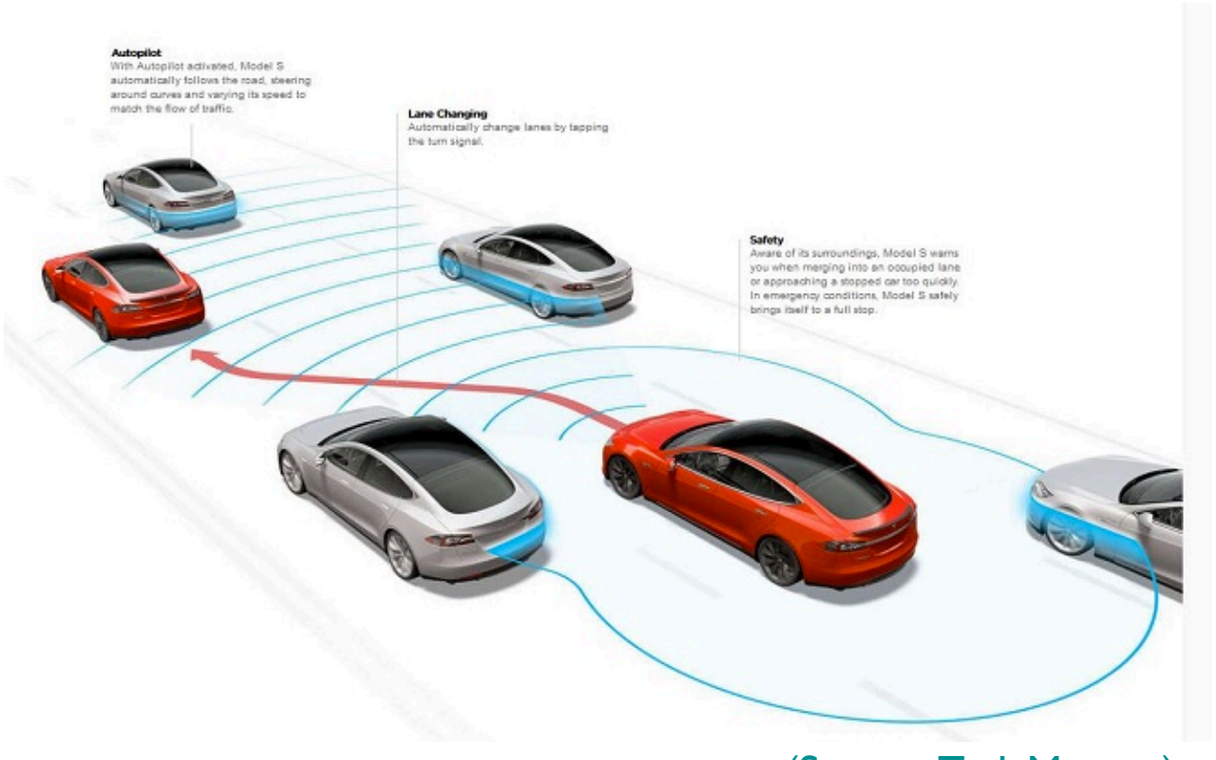
URLLC Use Cases

- **Assisted driving and transport services (1/3)**

  Intelligent Transport Systems

  - ITS refers to the use of IT, sensors and communications in transport applications, ***aiming at providing more efficient movement and seamless journeys for people***.

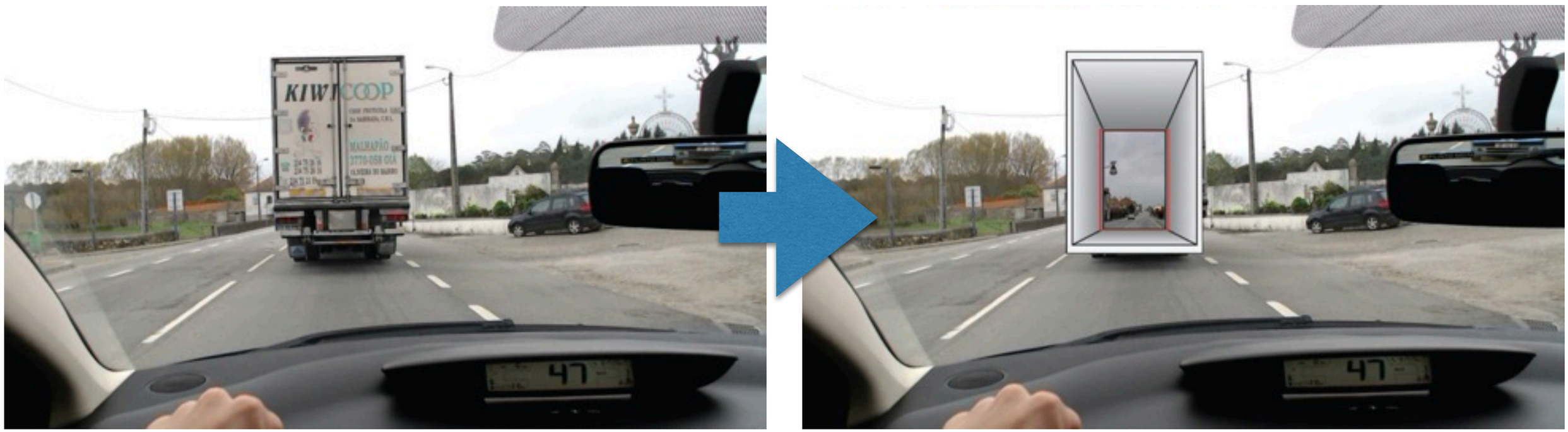
  - Automated overtaking systems require a maximum tolerable end-to-end latency of approximately ***10ms on each message exchange.***



(Source: TeslaMotors)

URLLC Use Cases

- **Assisted driving and transport services (2/3)**
  - When video is integrated as in the see-through application, encoding and decoding video would suppose prohibitive delays, thus very high data rates low latency are required to transmit real-time raw video.
    - For a 30 frames per second video feed, a capacity of 220Mbps and an end-to-end latency of 50ms shall be supported.



< See-through Application >

URLLC Use Cases

- **Assisted driving and transport services (3/3)**

✓ Low-level data (video streaming) transmissions in V2X

- Low-level data generated **by sensors (cameras, lidars, etc.)** is transmitted towards neighboring users (vehicles, infrastructure, tec.) to be fused and/or processed by the receiving system, in conjunction with its own sensors.

- Network requirement: high data rate (up to 10-20 Mbps) with a medium tolerance on errors (10^{-2})

✓ High-level data (objects) transmissions in V2X

- High-level data generated **after sensor processing (object recognition, Radar or LiDAR target lists)** is transmitted to neighboring users (vehicles, infrastructure, etc.) to be fused by the receiving systems in conjunction with its own sensors.

- Network requirement: medium data rate (up to 1 Mbps) with a very low tolerance on errors (10^{-5})

(Source: 5G PPP)

URLLC Use Cases

- **Entertainment: content delivery and gaming (1/2)**
  - An ultra-reliable low latency network capable of providing the fully immersive multi-sensorial services, through video, audio and tactile can further enhance the consumer experience, in both content delivery and gaming
  - For virtual reality and augmented reality, 7~15ms application to application delay, i.e., action to reaction, is the threshold to provide a smooth action-reaction experience
  - To reduce the processing burden in the device end, 5G should integrate high processing in mobile edge computing clouds

(Source: Microsoft)

URLLC Use Cases

- **Entertainment: content delivery and gaming (2/2)**
  - Visual interaction
    - Response time within **5ms** is required for tracking the change of viewpoint.
    - Latency within **5ms** is required to synchronize to human movements
  - Auditory interaction
    - Less than **50ms** delay is required to synchronize to visual changes
  - Tactile interaction
    - Less than **1ms** delay is required to prevent cyber sickness
      : ***Cyber sickness*** is a condition in which a disagreement exists between visually perceived movement and the viewing movement via mobile/electronic devices.

URLLC Use Cases

- **Industry automation**
  - To digitise the industry to provide higher value products and processes by intelligent networking of product development and production, logistics and customers
  - Time critical process optimization and control → Latencies in these use-cases may go below 1ms
    - Realtime optimization based on instantly received information from monitoring or interaction between different operators
    - Remote control robotic operations
    - Collaborative robots in closed-loop control systems.

(Source: Starship Groove)

URLLC Service Requirements

Industry Vertical	Requirements	Value
Healthcare	• Robotic tele operations (surgery or remote control of robots in any other application) that require haptic information feedback need to have stable latencies that are below the round trip values of 10ms	***RTT 10ms***
Automotive	• 10ms one way delay in cooperative driving • Safety related applications in the automotive industry require end-to-end delay as little as 10ms • 36m cars with SIM cards to be sold by 2018	***E2E 10ms***
Entertainment	• As low as 7ms round trip delay to support VR/AR for supporting a full immersive experience	***RTT 7ms***
Manufacturing	• Sub 1ms one way delay in control applications • Cyber-physical systems to play primary role	***OW 1ms***

(Source: M. Dohler'17)

URLLC Challenges and Conclusions

End-to-End Latency in 5G Networks

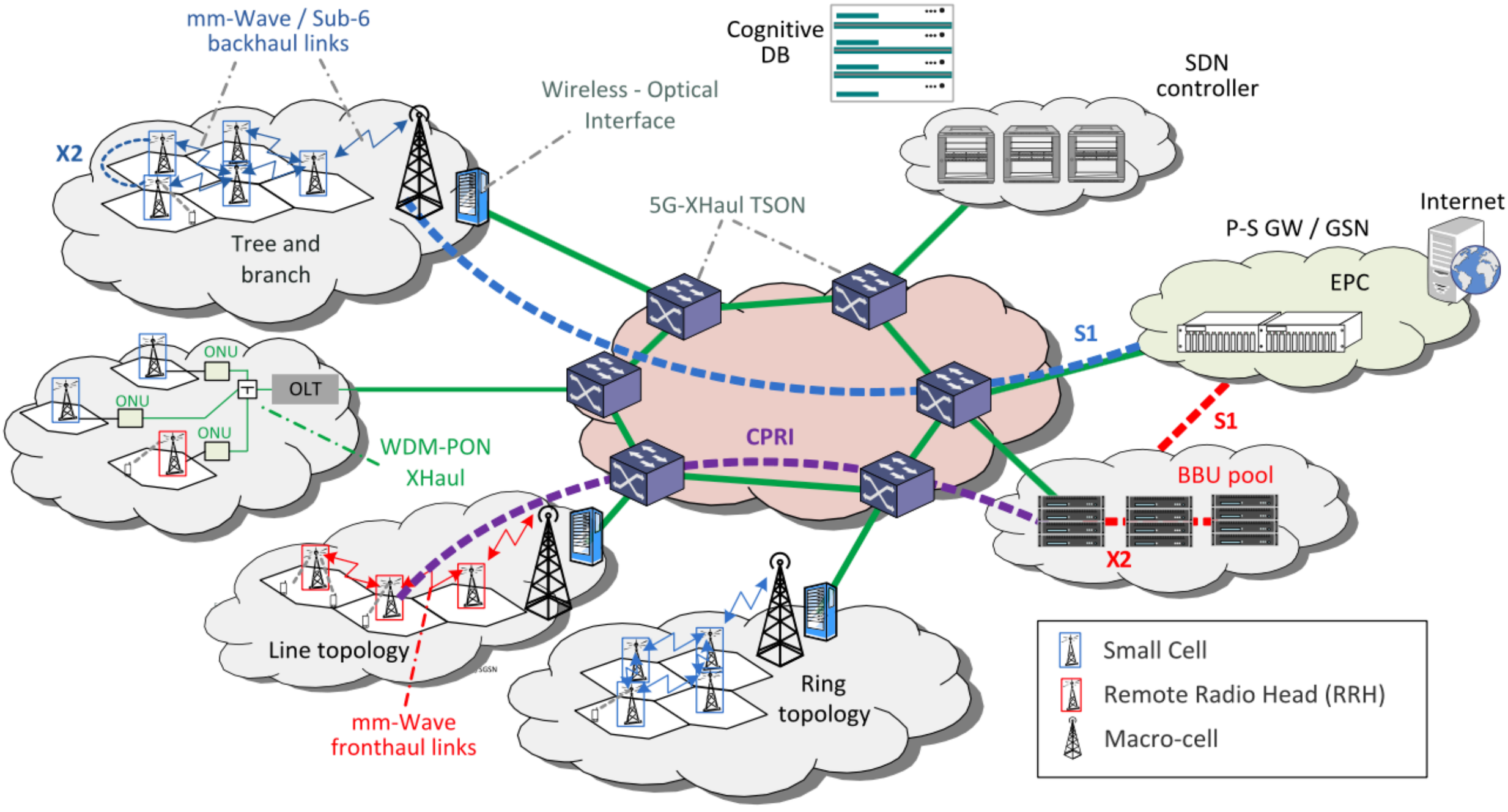


Figure 1.1: 5G-XHaul Network Deployment

(Source: 5G PPP)

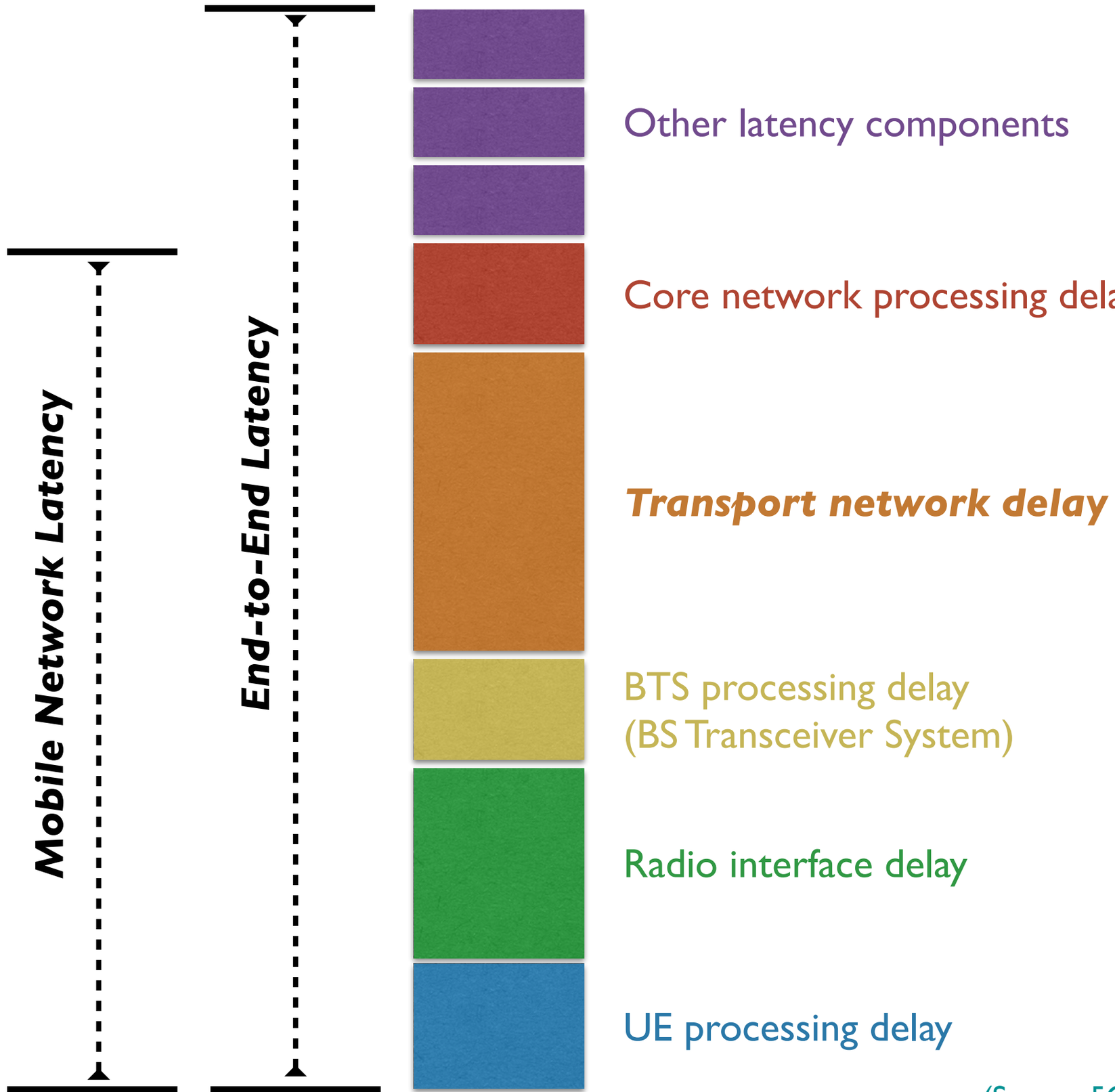
End-to-End Latency in 5G Networks

Dynamic resource allocations

Mobile edge computing

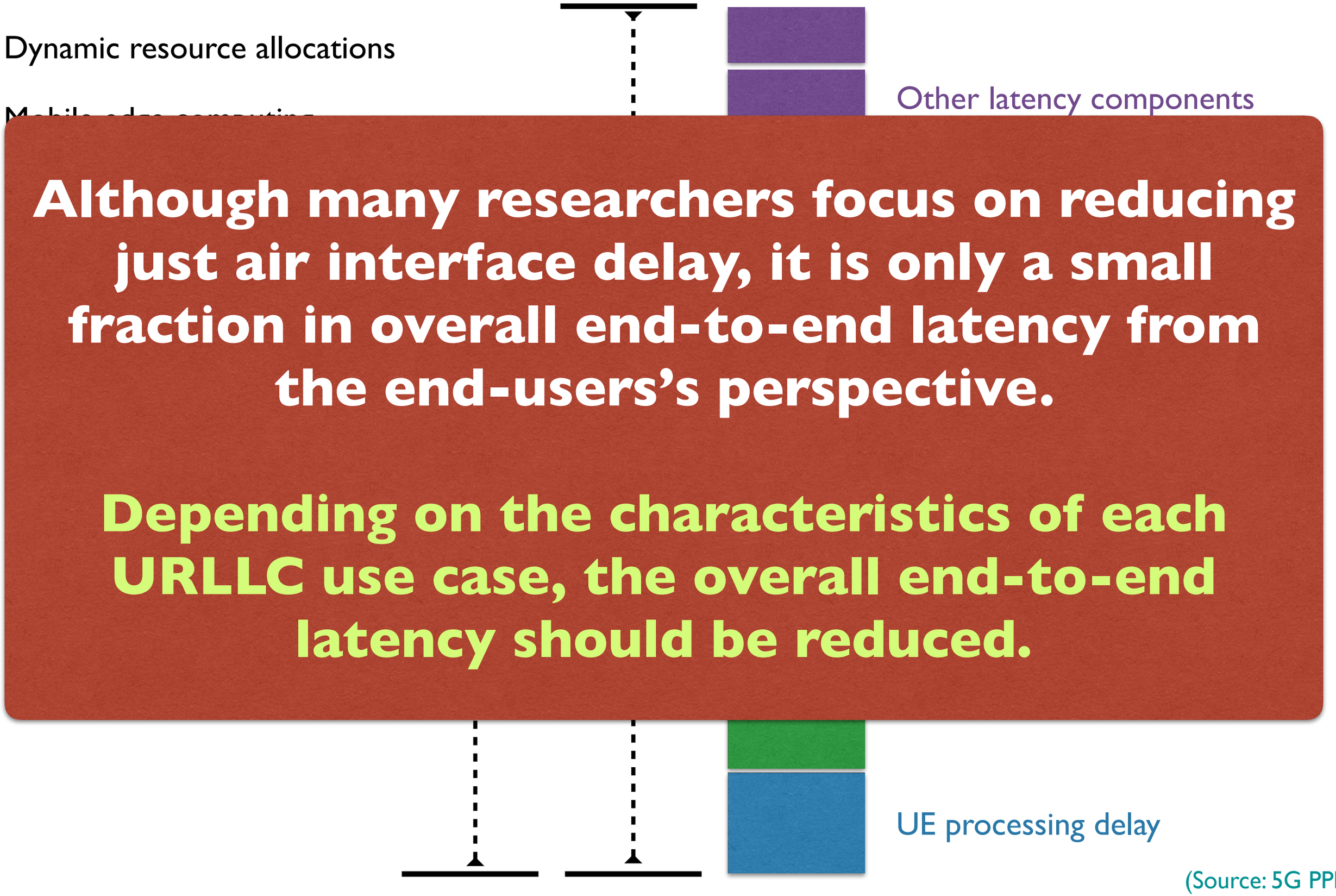
Higher data rates

Functional split
(CP/UP, RU/DU)



(Source: 5G PPP)

End-to-End Latency in 5G Networks



Although many researchers focus on reducing just air interface delay, it is only a small fraction in overall end-to-end latency from the end-users's perspective.

Depending on the characteristics of each URLLC use case, the overall end-to-end latency should be reduced.

(Source: 5G PPP)

Thank you.

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