이동통신 기술

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hwkim7@gmail.com

v0.71

목차

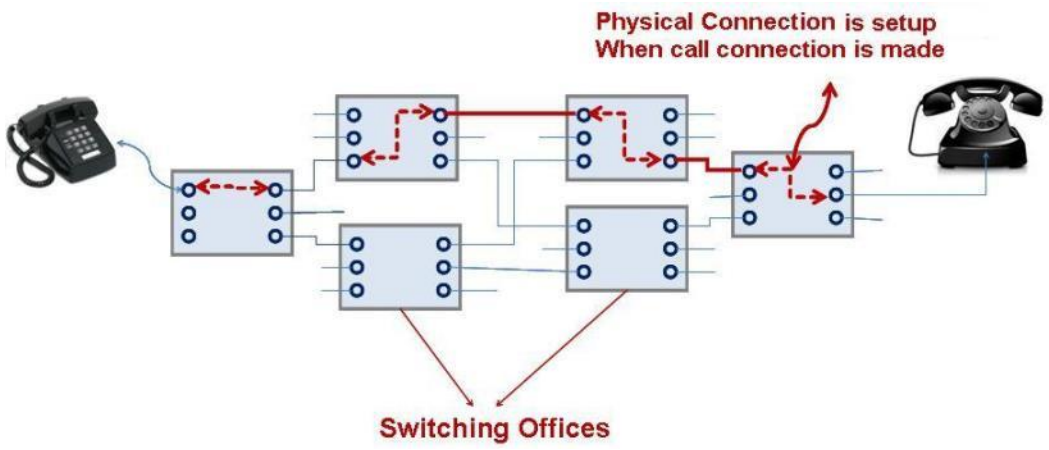
개요

유선전화와 이동전화

유선전화

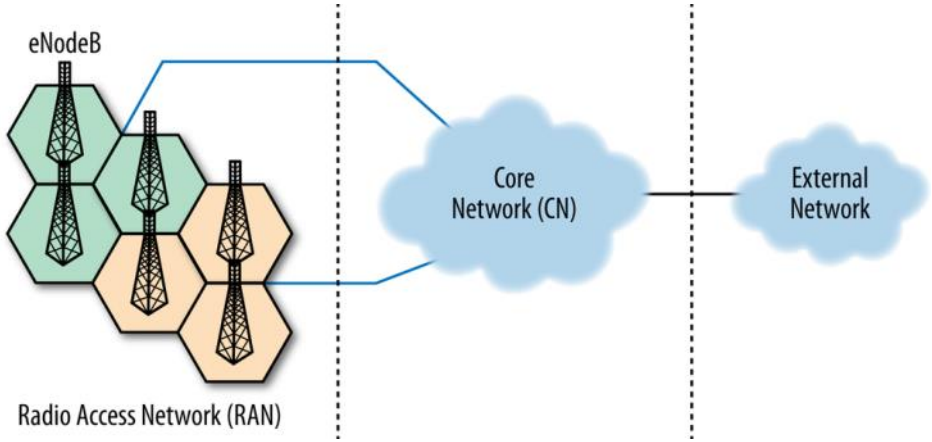
이동전화

유선전화망과 이동전화망



교환기

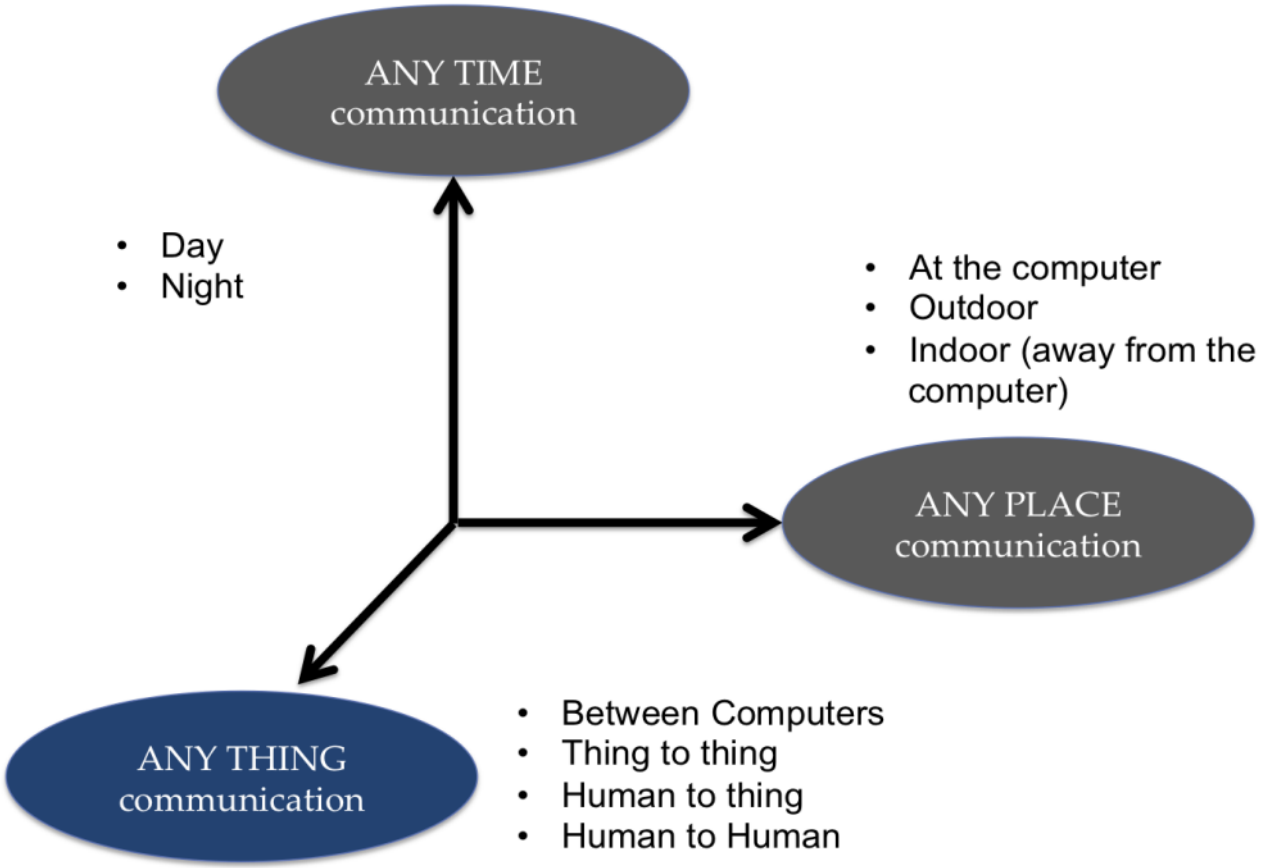
Anytime Comm.



전파
기지국
단말기 이동관리

Anytime Comm.
Anyplace Comm.

Comm. Domain Extension



이동통신 장비 예

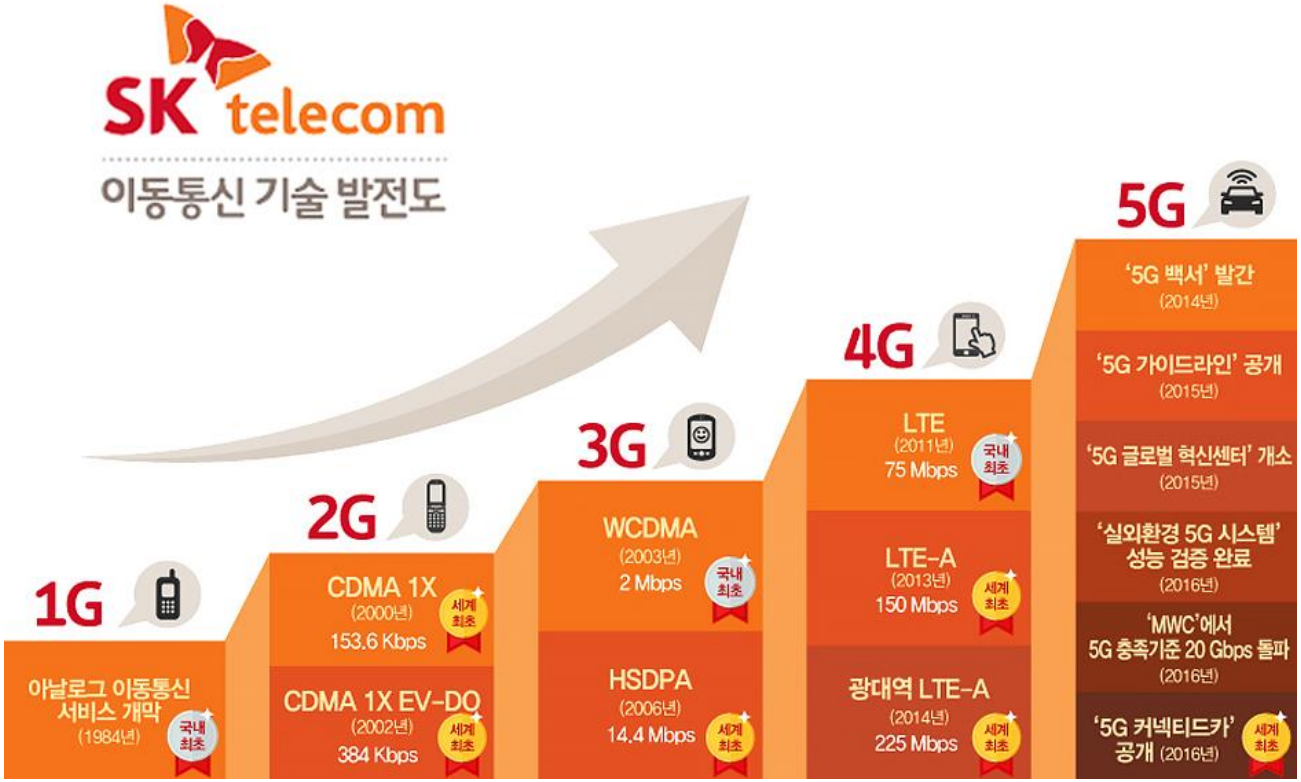
Core Network 장비

BBU

RRH

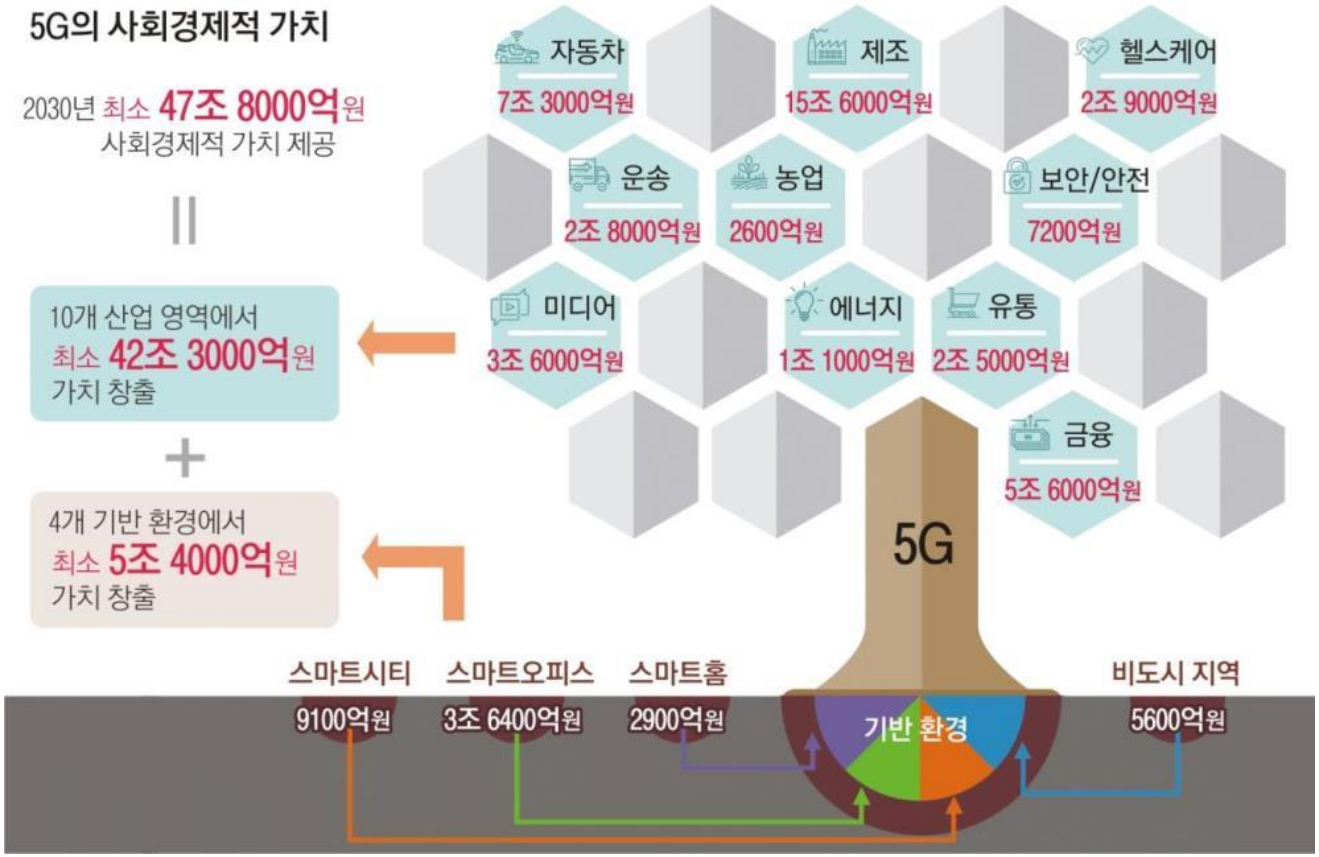
Radio Access Network 장비

이동통신 발전과정

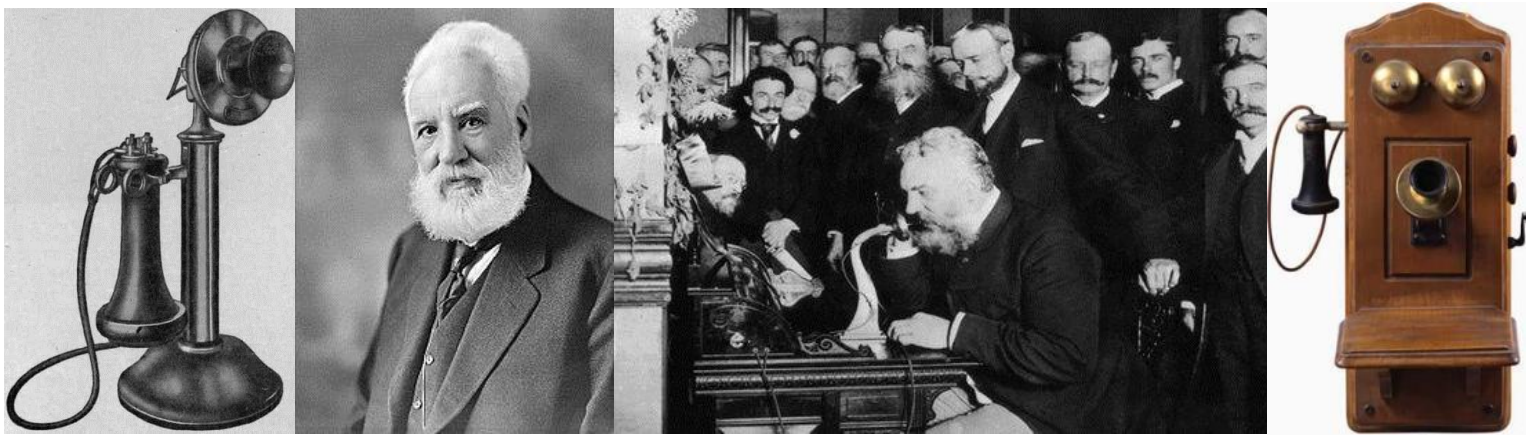


- 10년 주기로 이동통신 기술발전, Download 속도 증가 위주로 기술정의
- OFDMA 사용, Shannon 한계치에 도달, 새로운 주파수 필요(5G)
- 5G부터 3GPP로 표준 단일화, 전체 산업에 영향, 주요 국가간 기술 경쟁

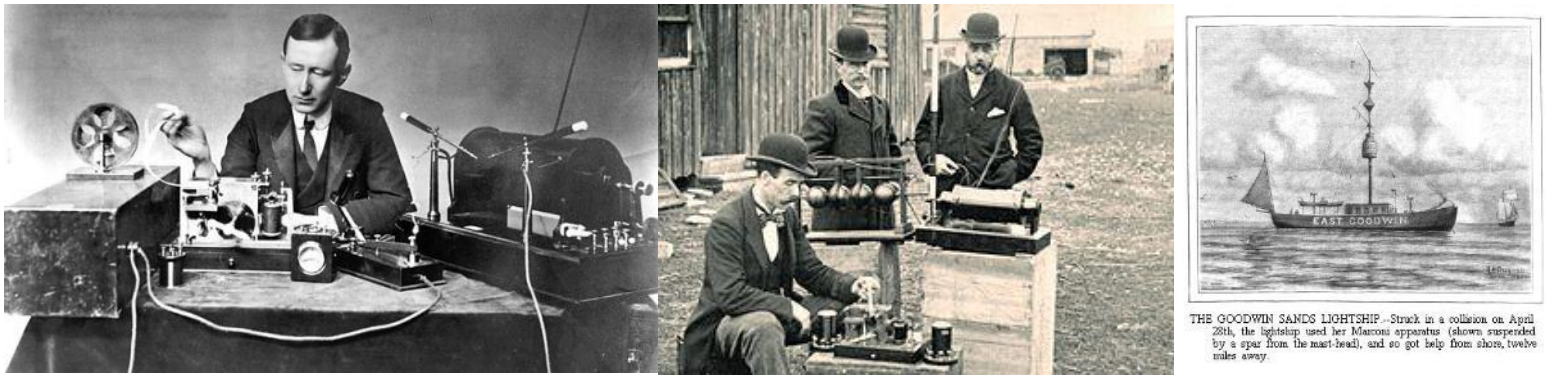
5G 이동통신 경제적 효과



유선전화, 무선전화 시작



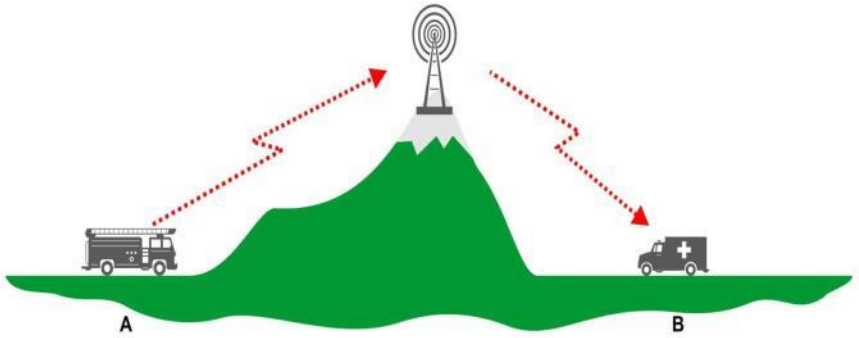
유선전화 발명(1876년): Alexander Graham Bell



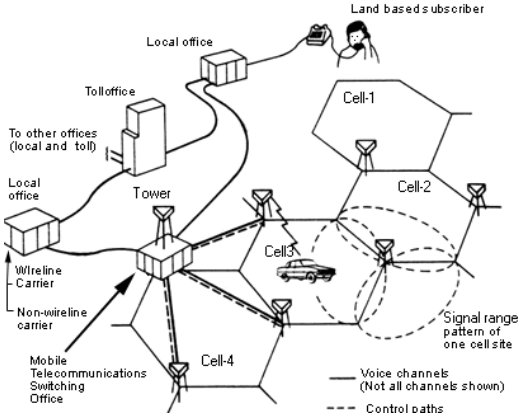
THE GOODWIN SANDS LIGHTSHIP.—Struck in a collision on April 28th, the lightship used her Marconi apparatus (shown suspended by a spar from the mast-head), and so got help from shore, twelve miles away.

무선통신 발명(1896년): Guglielmo Marconi

무선통신, 이동전화

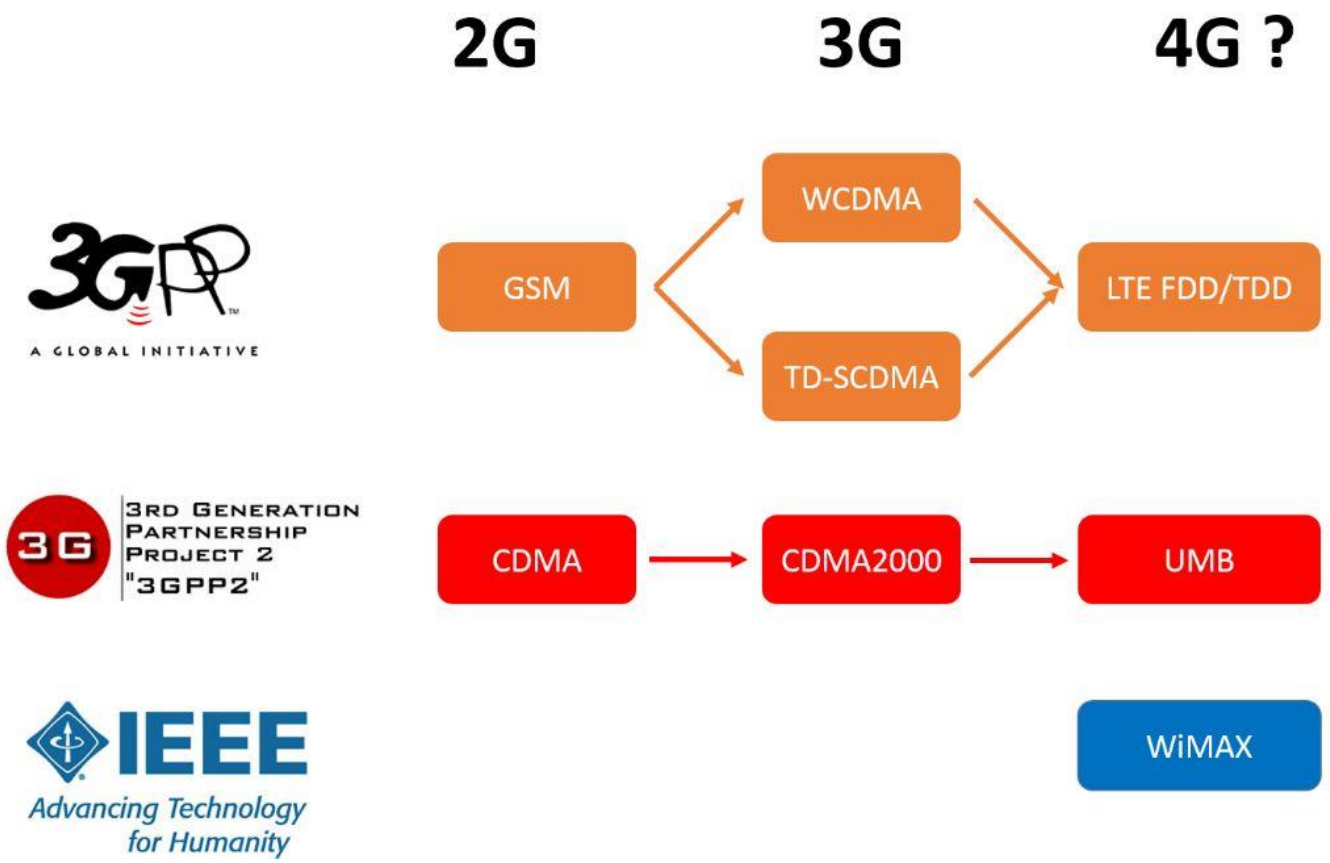


하나의 기지국을 활용한 무선통신(1970년대)



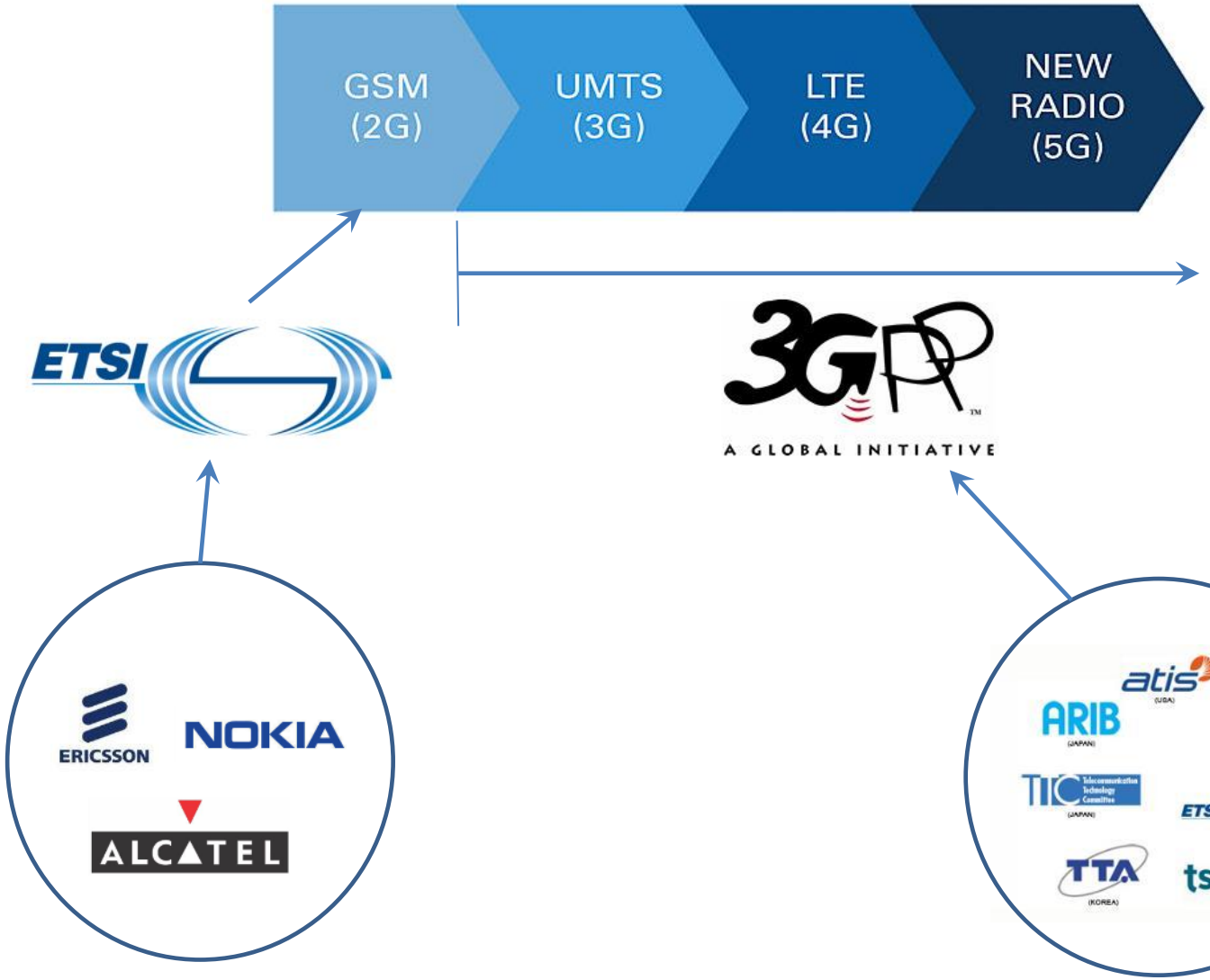
AMPS 셀룰라 이동통신(1983년) – Bell Labs

표준화 단체: 3GPP, 3GPP2, IEEE



* 3GPP: 3rd Generation Partnership Project
* 3GPP2: 3rd Generation Partnership Project 2
* IEEE: Institute of Electrical and Electronics Engineers

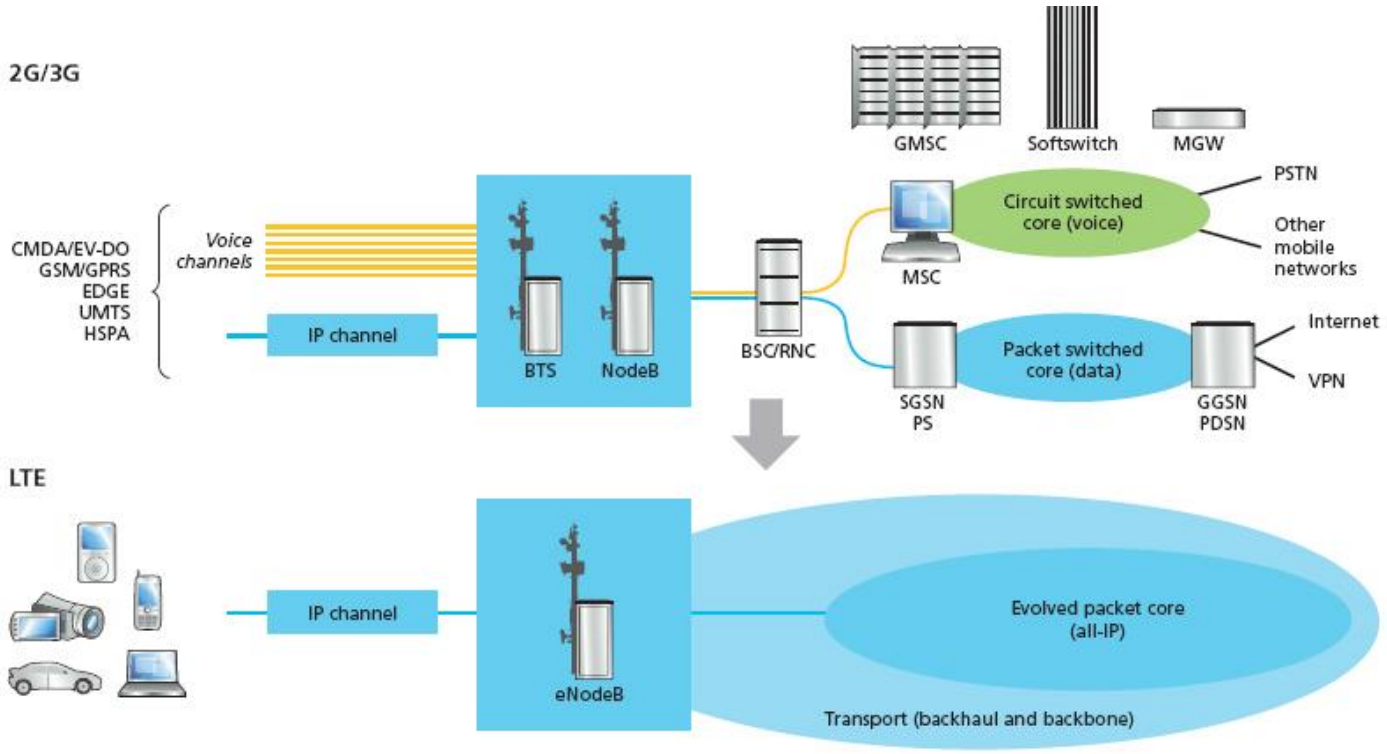
ETSI, 3GPP

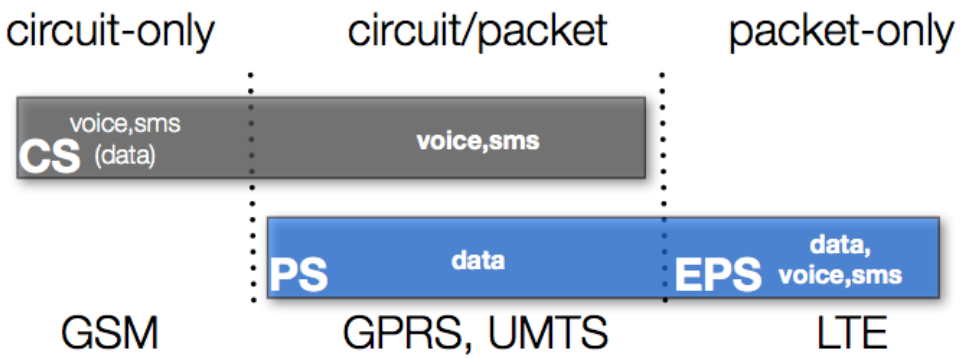


* ETSI: European Telecommunications Standards Institute
* 3GPP: 3rd Generation Partnership Project

* UMTS: Universal Mobile Telecommunications System
* LTE: Long Term Evolution, NR: New Radio

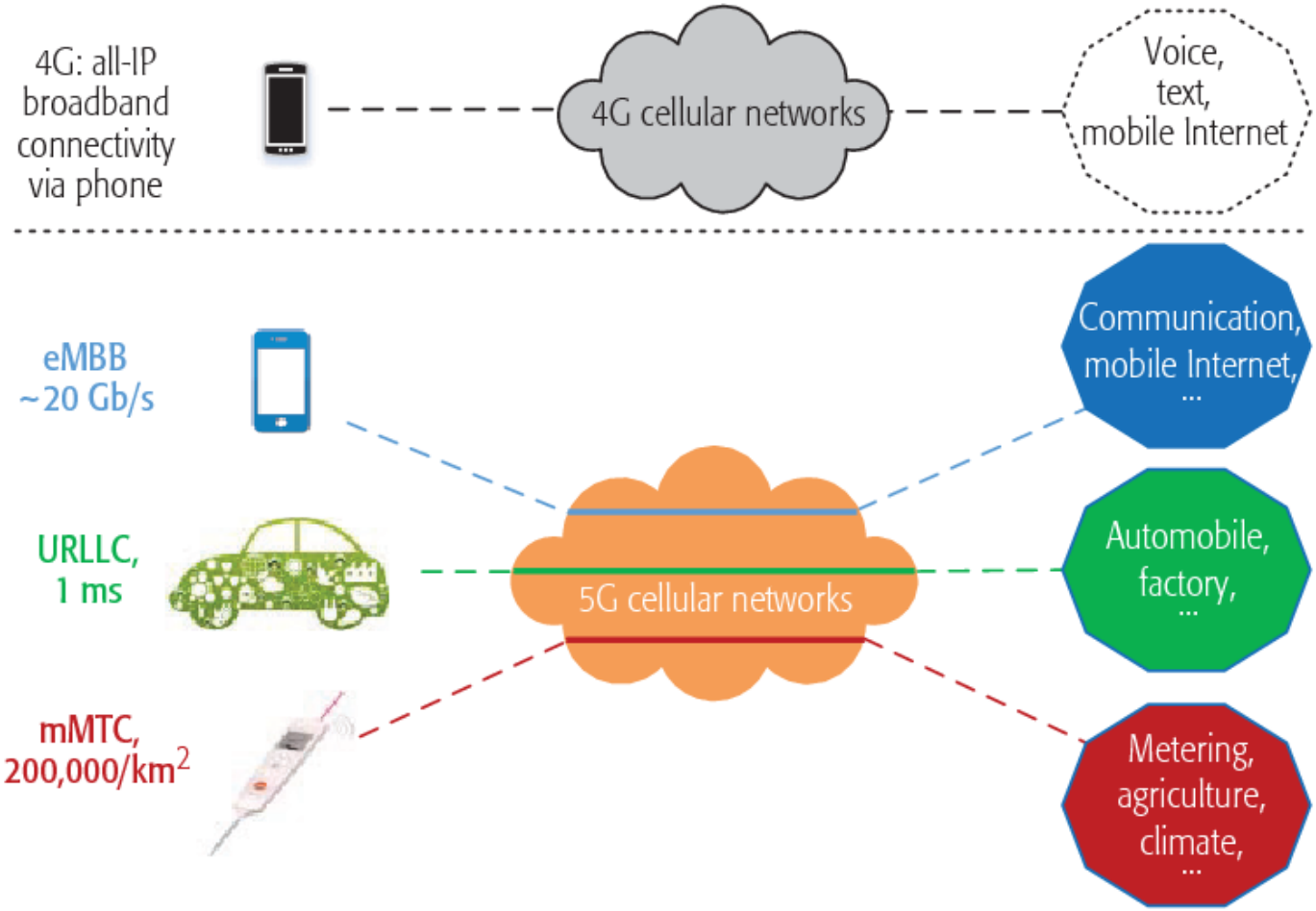
3G, 4G망 비교





CS: Circuit-Switching, PS: Packet-Switching, EPS: Envolved-Packet-System

4G와 5G 망구성 비교



* eMBB: enhanced Mobile Broadband
* mMTC: massive Machine Type Communication
* URLLC: Ultra Reliable Low Latency

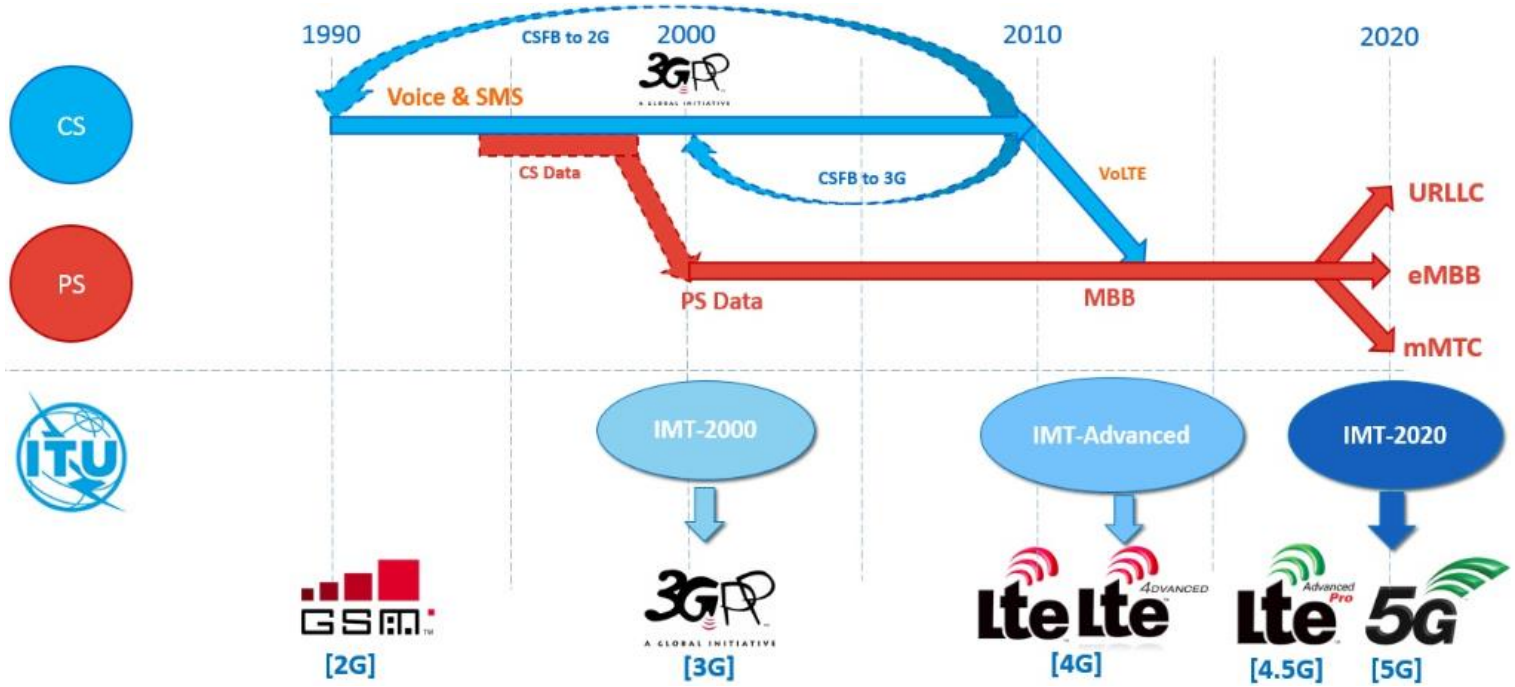
3G, 4G, 5G 비교

UMTS(3G)	LTE(4G)	NR(5G)
		
전화선	LAN 선	광 케이블
		
집전화	일반 PC	고성능 PC

< 용어 유래 >
UMTS: Global
LTE: Shannon Limit
NR: Sub-6, mmWave

* UMTS(3G): Universal Mobile Telecommunications System
* LTE(4G): Long Term Evolution, * NR(5G): New Radio

용어정의

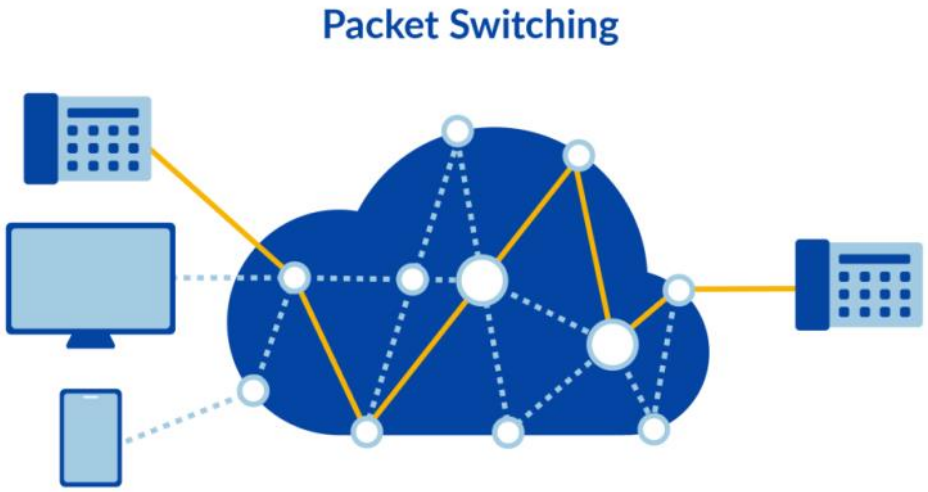


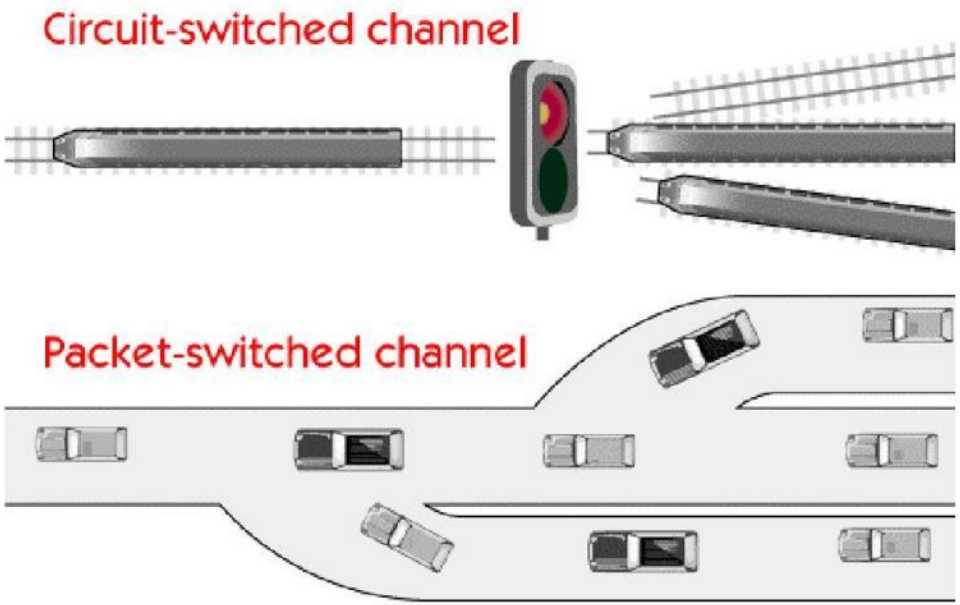
IMT-2020, NR(New Radio), 5G
유럽식 영어로 정의한 용어 ?

* UE=MS
* RAN=BS

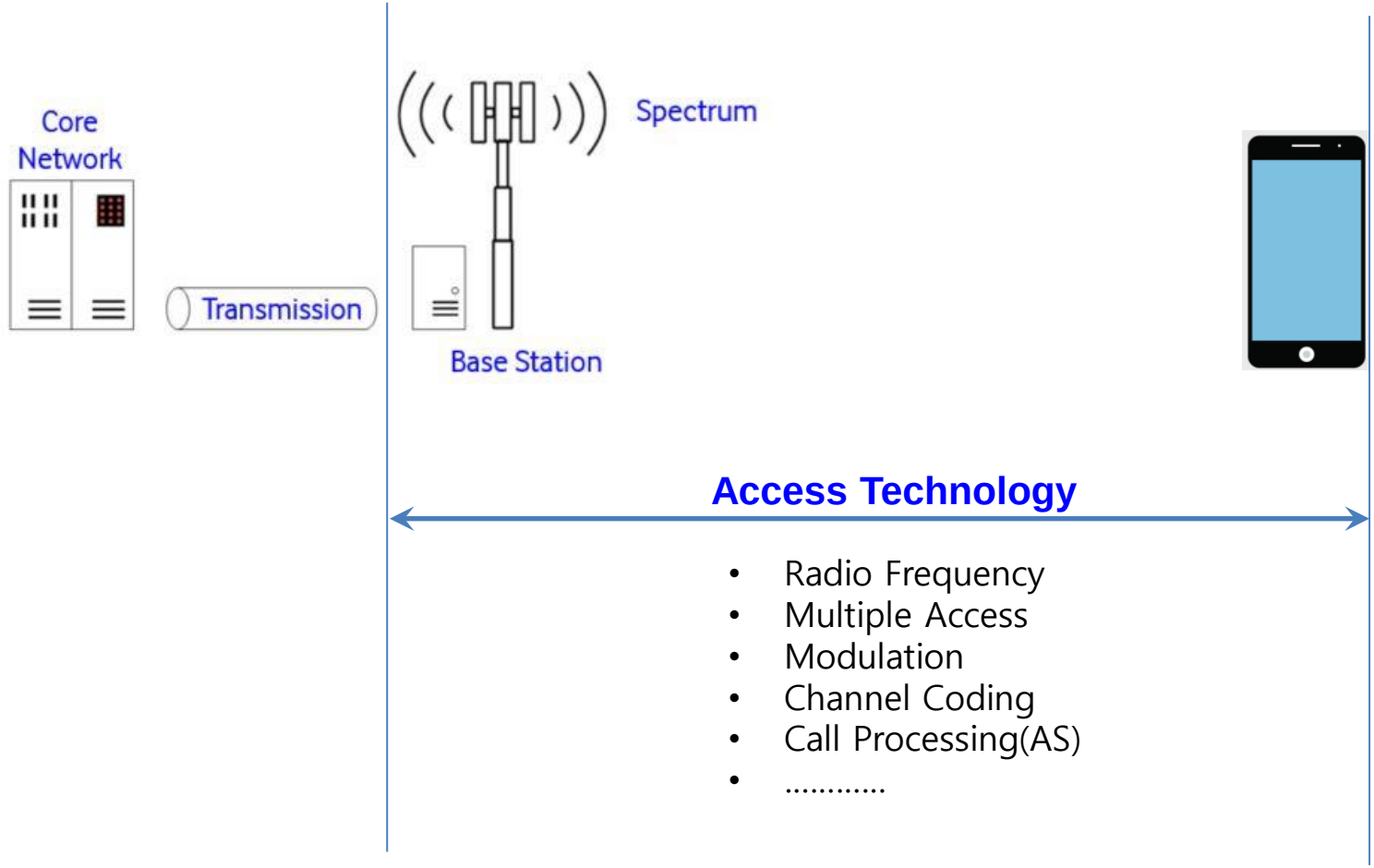
* eMBB: enhanced Mobile Broadband
* mMTC: massive Machine Type Communication
* URLLC: Ultra Reliable Low Latency

Packet Switched Network





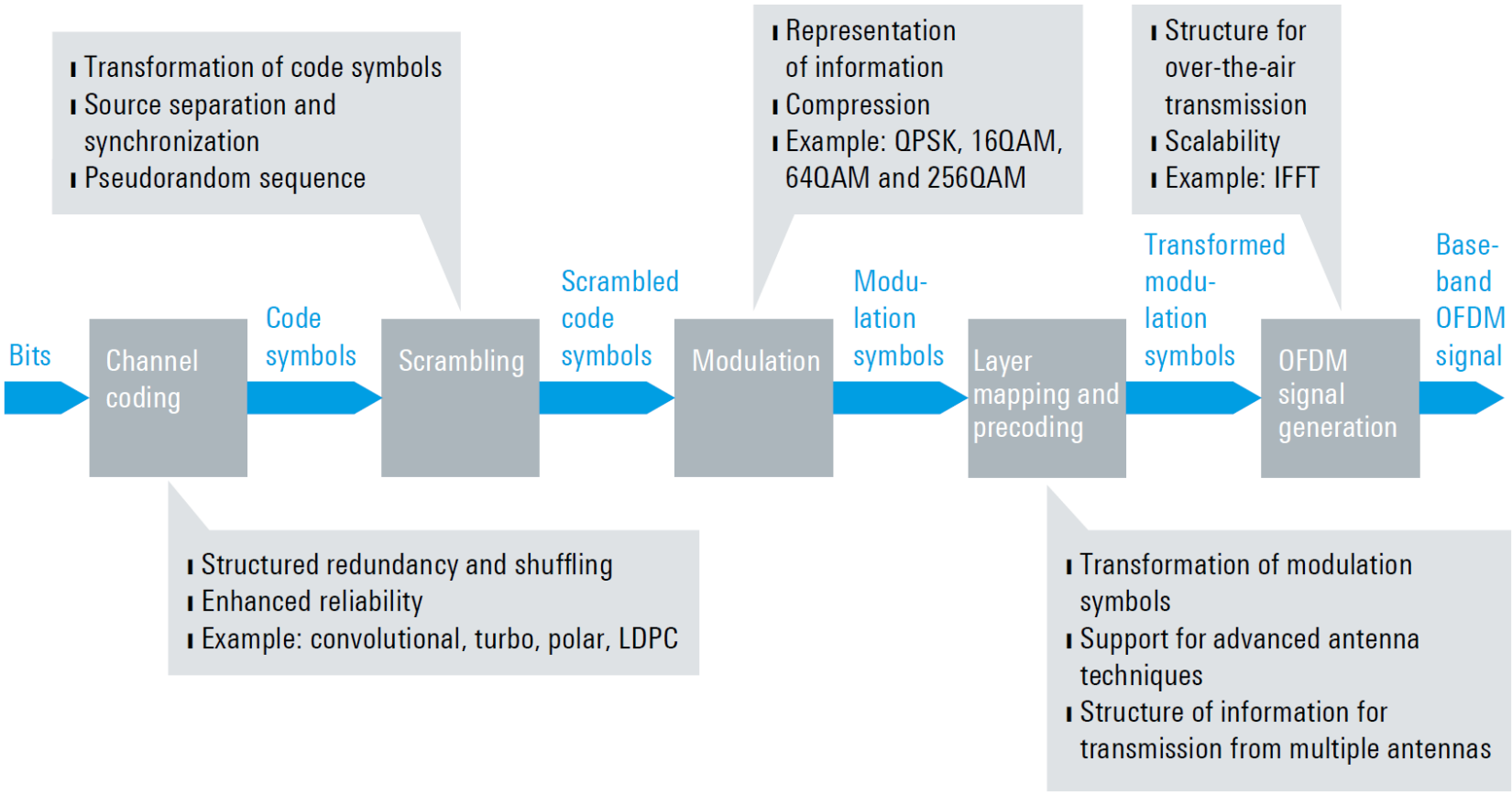
주요 기술 분야



< Cellular Network Assumption >
* Radio Access Network: Limited Resources
* Core Network: Unlimited Resources

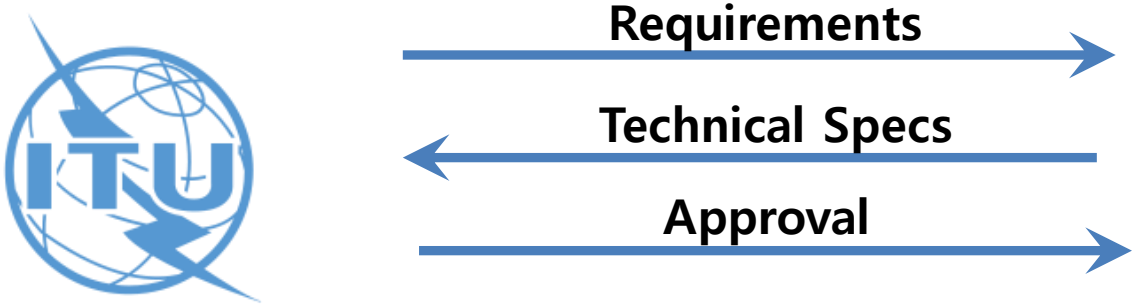
< 문맥에 따라 용어 해석 >
* 거시기, 시스템, Data, 망

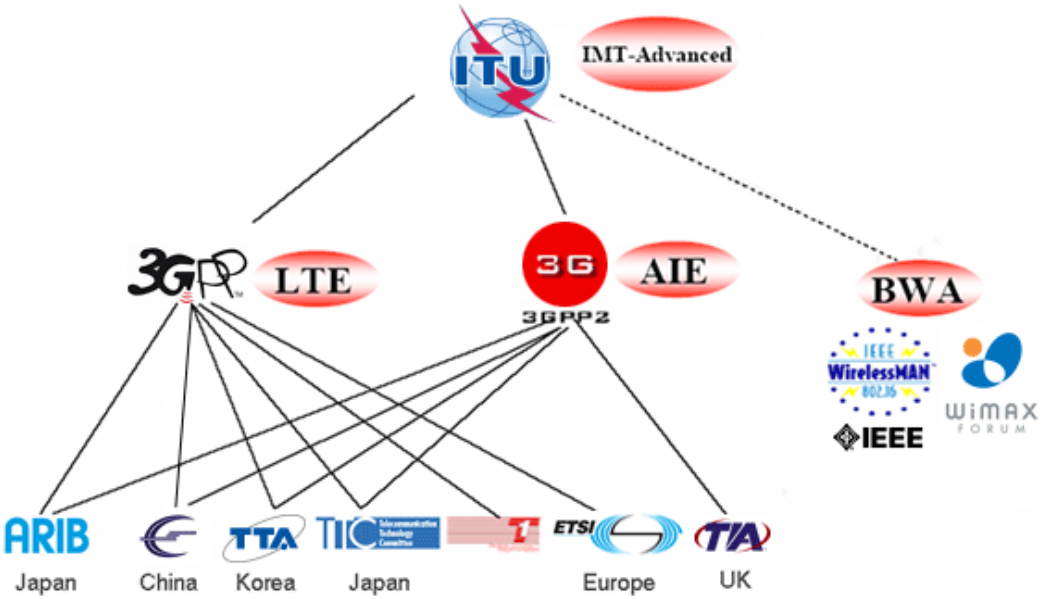
Physical Layer Processing(Baseband, OFDMA Tx)



표준화

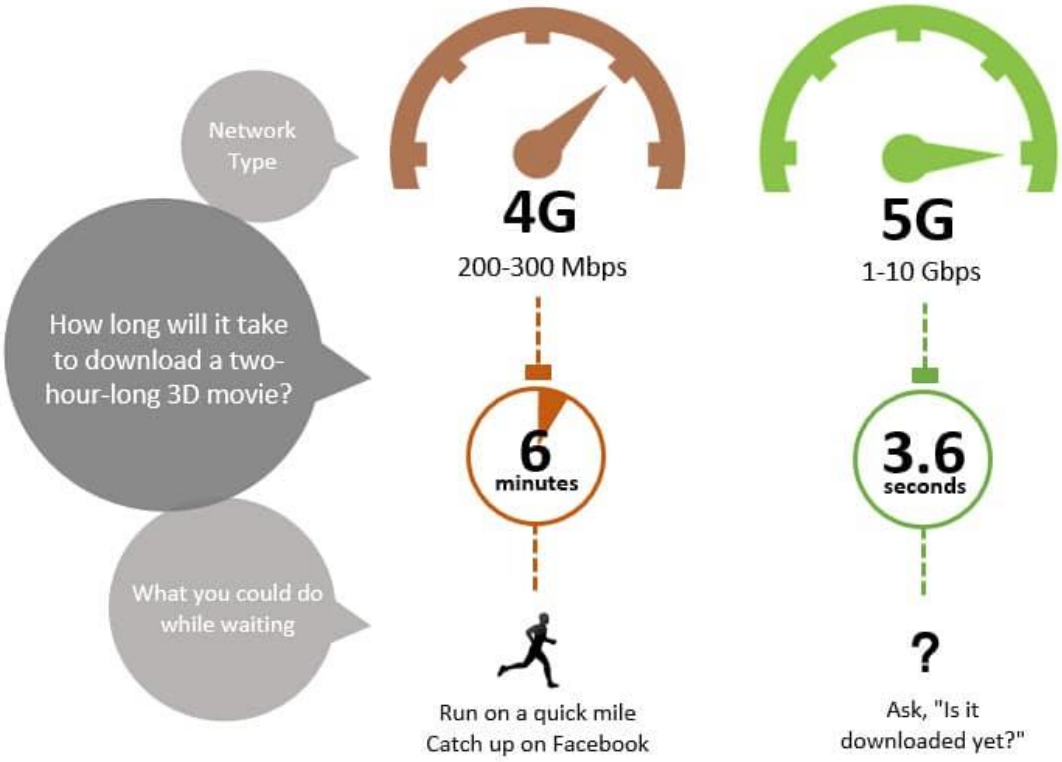
ITU와 3GPP 관계





* ITU: International Telecommunication Union
* IMT: International Mobile Telecommunications
* UN: United Nations

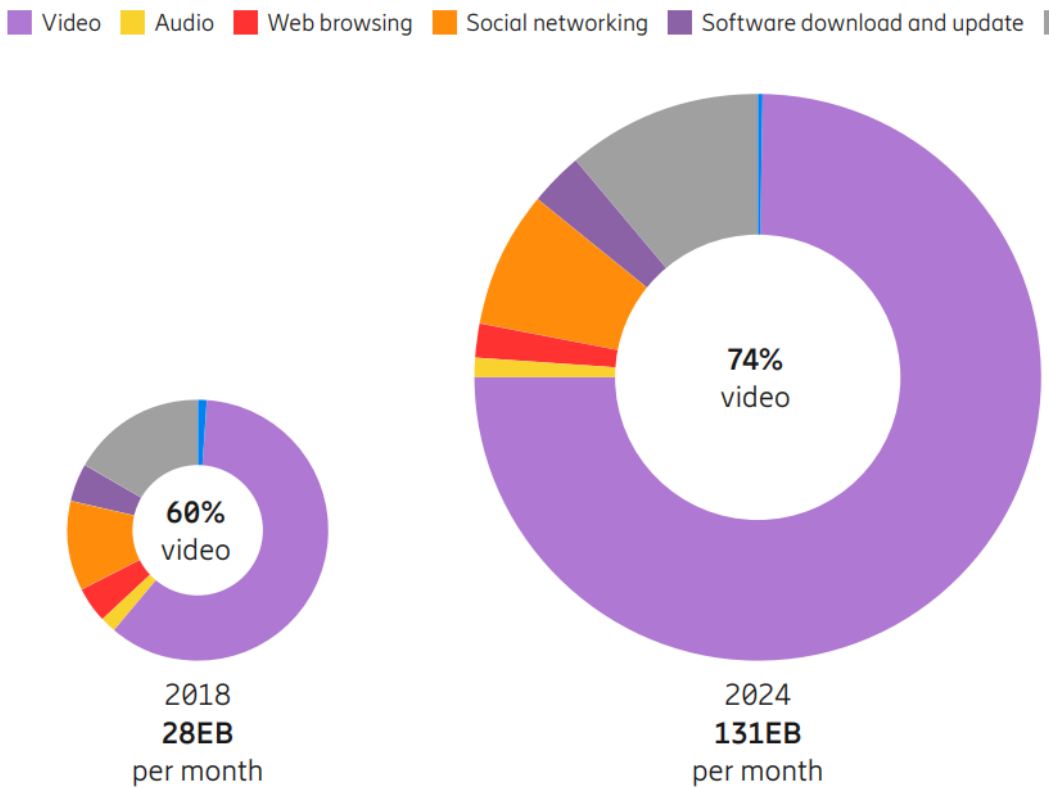
표준화 방향 – High Speed Download



- 4G, 5G의 주된 표준화 방향성은 Download 데이터 속도 증대
- 5G는 Access 기술과 함께 Core Network에도 많은 기술 추가
  - SBA, Network Slicing, MEC, 다양한 QoS 처리

Mobile Traffic 증가

Mobile data traffic by application category per month (percent)

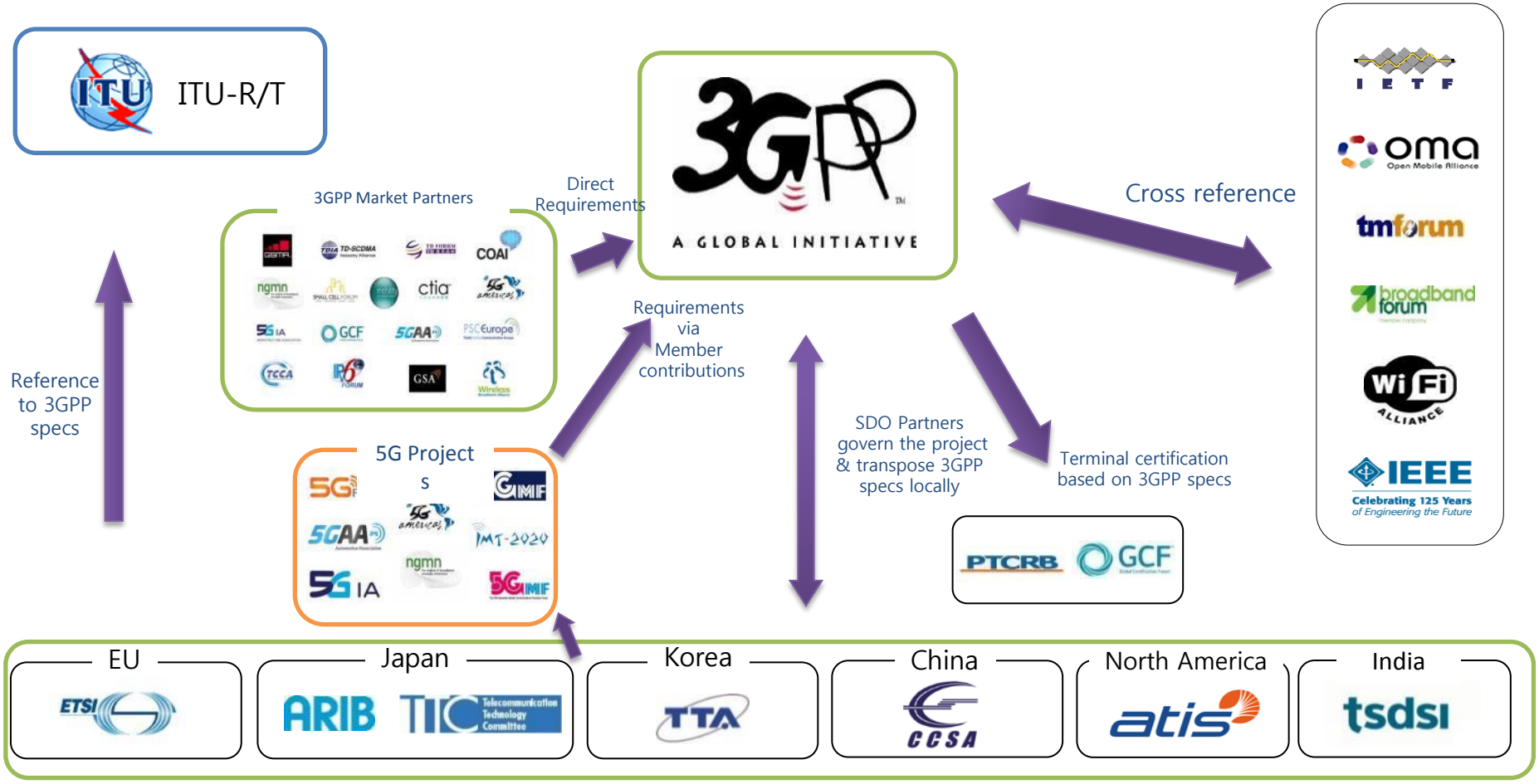


Main drivers for video traffic growth

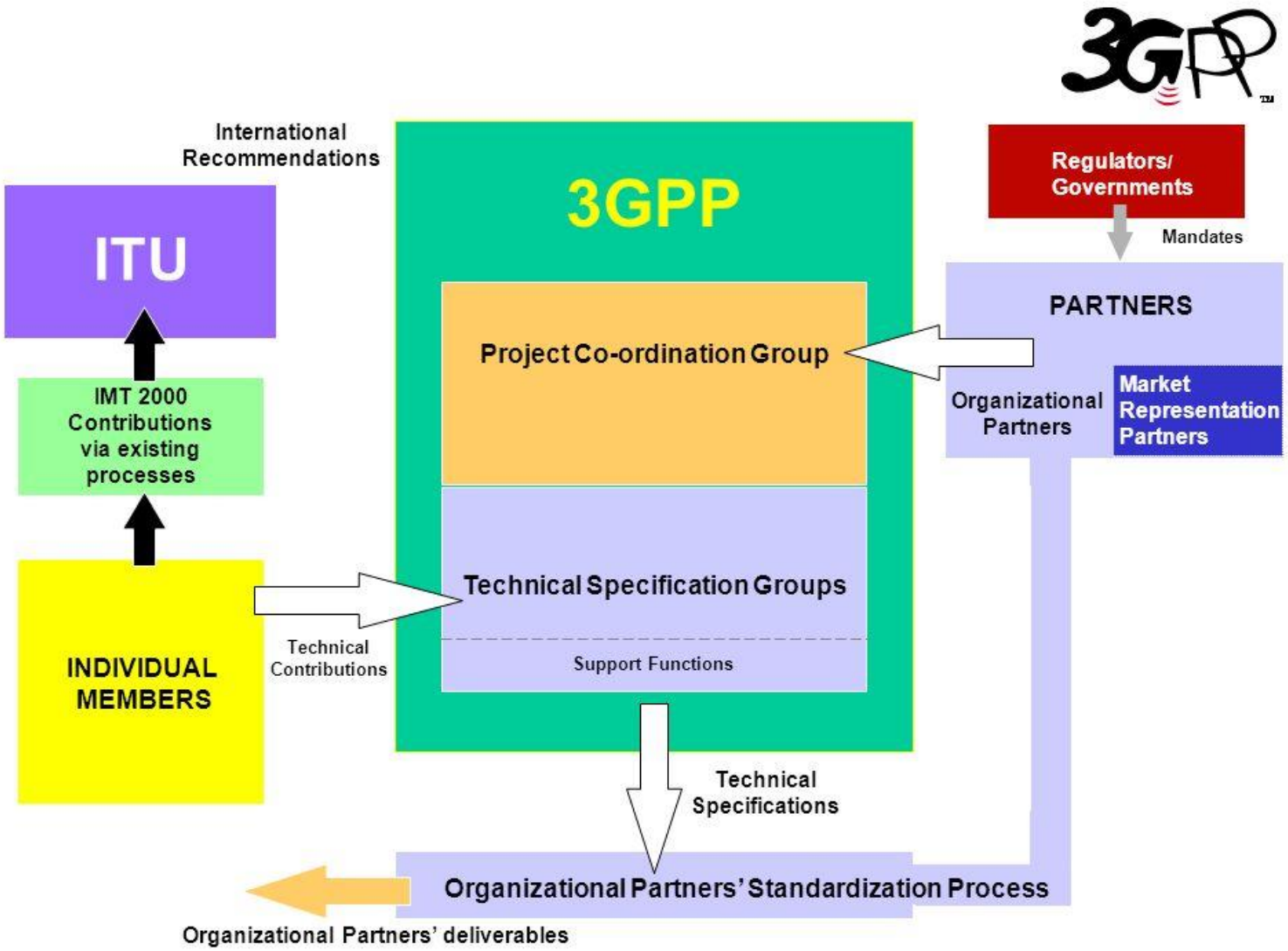
- Video part of most online content (news, ads, social media, etc.)
- Growth of VoD services
- Video streaming services
- Changing user behavior – video being consumed anywhere, any time
- Increased segment penetration, not just early adopters
- Evolving devices with larger screens and higher resolutions
- Increased network performance through evolved 4G deployments
- Emerging immersive media formats and applications (HD/UHD, 360-degree video, AR, VR)

[1] Traffic from embedded video in web browsing and social media is included in the application category "Video"
[2] Ericsson ConsumerLab, 5G consumer potential study (May 2019)

3GPP Ecosystem



3GPP Standardization Process

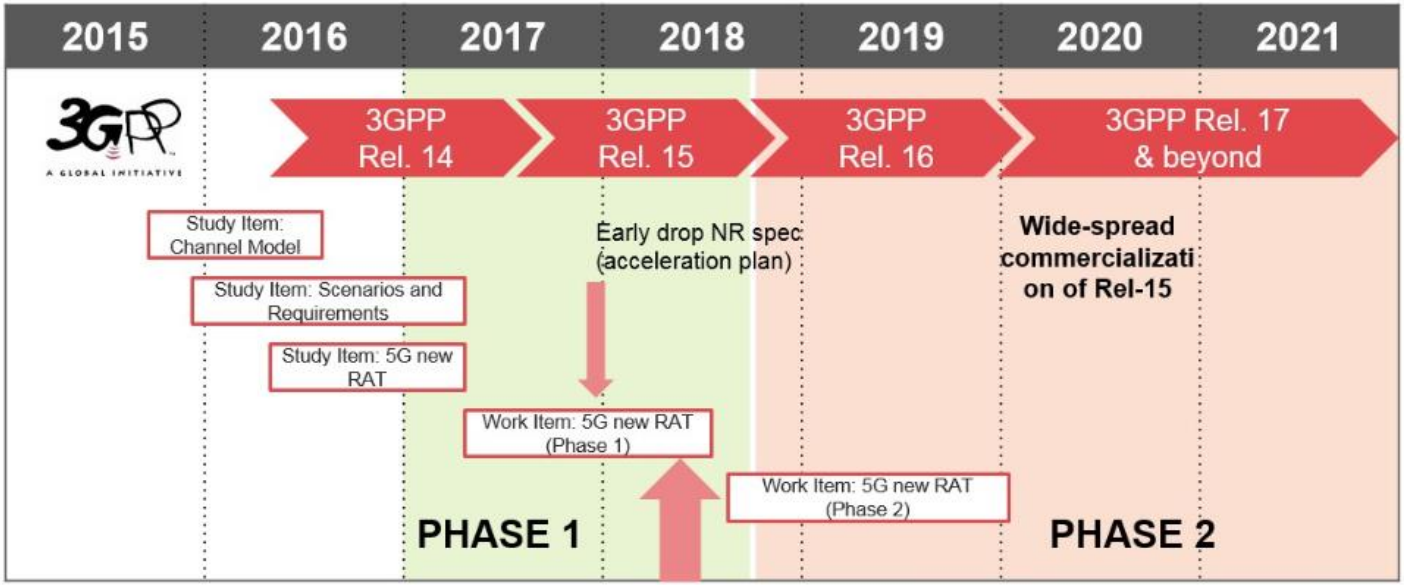


3GPP 규격 정의 그룹

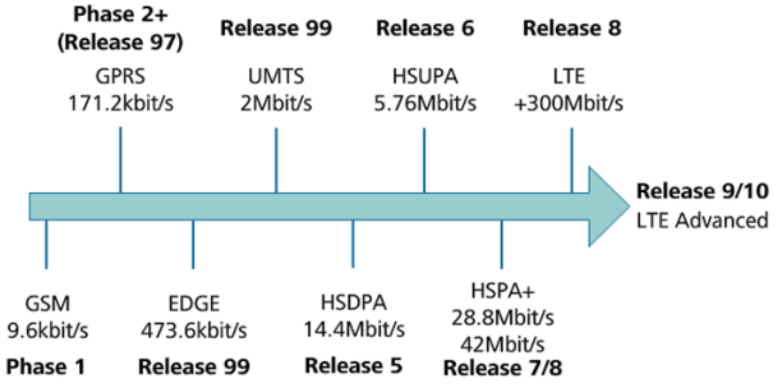
Project Coordination Group (PCG)

TSG RAN Radio Access Network	TSG CT Core Network & Terminals	TSG SA Service & Systems Aspects
RAN WG1 Radio Layer 1 spec	CT WG1 MM/CC/SM (lu)	SA WG1 Services
RAN WG2 Radio Layer 2 spec Radio Layer 3 RR spec	CT WG3 Interworking with external networks	SA WG2 Architecture
RAN WG3 lub spec, lur spec, lu spec UTRAN O&M requirements	CT WG4 MAP/GTP/BCH/SS	SA WG3 Security
RAN WG4 Radio Performance Protocol aspects	CT WG6 Smart Card Application Aspects	SA WG4 Codec
RAN WG5 Mobile Terminal Conformance Testing		SA WG5 Telecom Management
RAN WG6 GSM EDGE Radio Access Network		SA WG6 Mission-critical applications

3GPP Release 현황

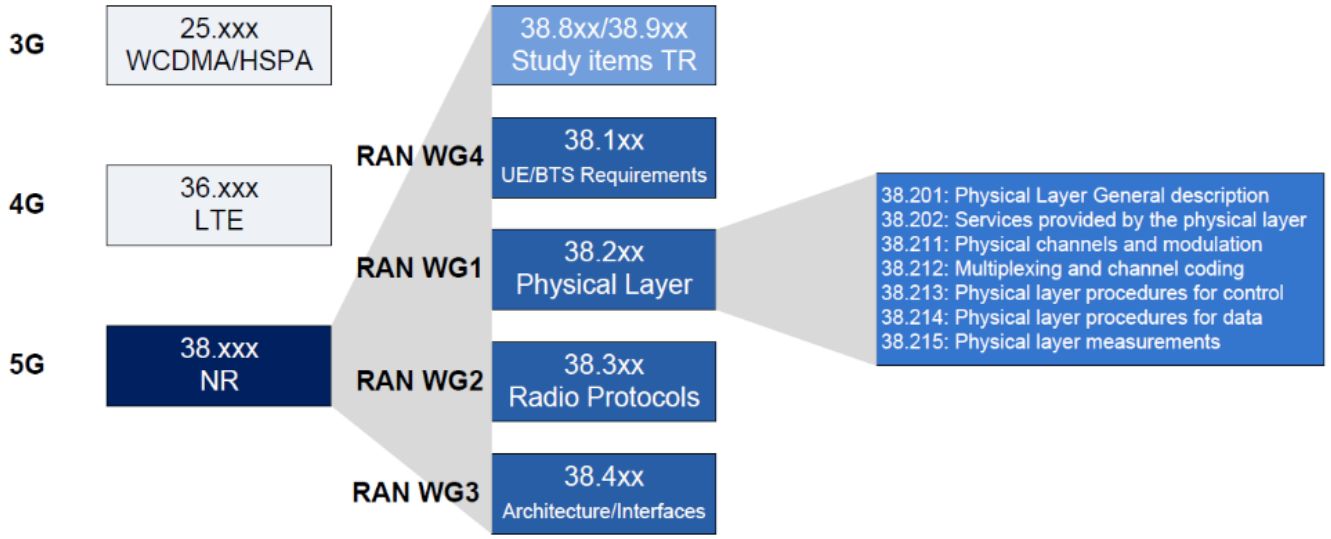


3GPP Evolution



* RAT: Radio Access Technology

3GPP Technical Specs 예



3GPP TS 38.201 V15.0.0 (2017-12)

Technical Specification

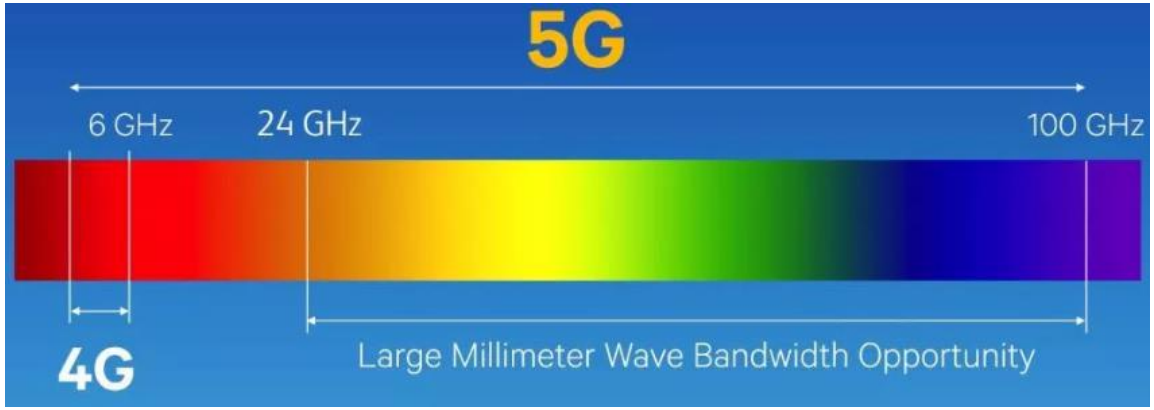
3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
NR;
Physical layer; General description
(Release 15)

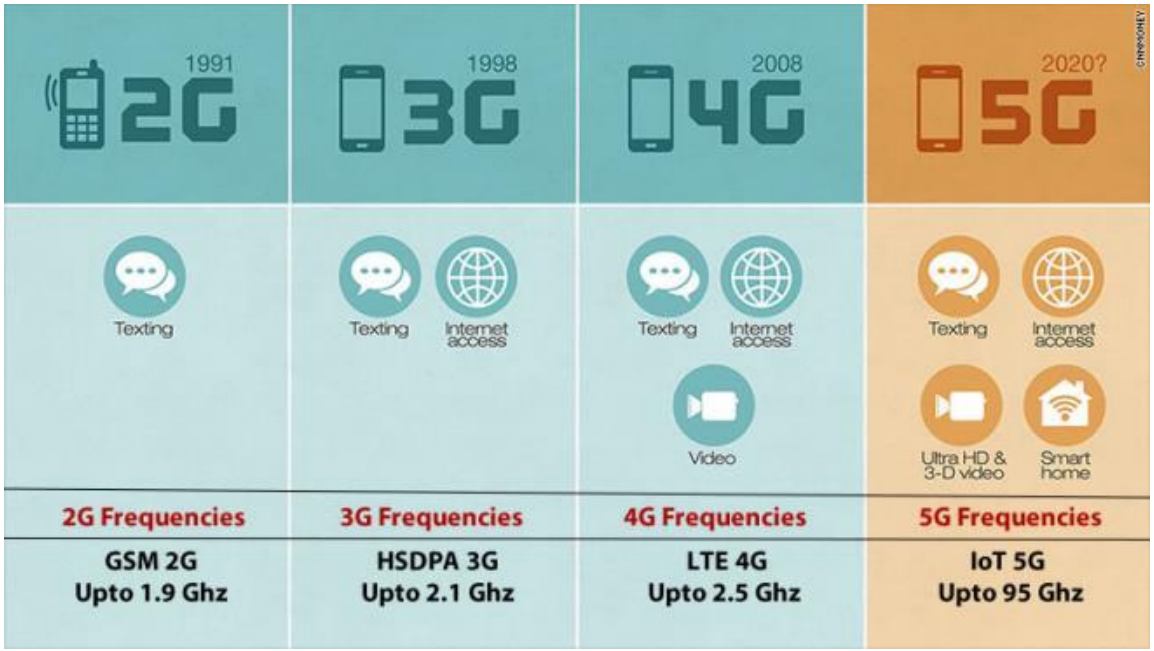
3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Study on Scenarios and Requirements for
Next Generation Access Technologies;
(Release 15)

전파, 주파수

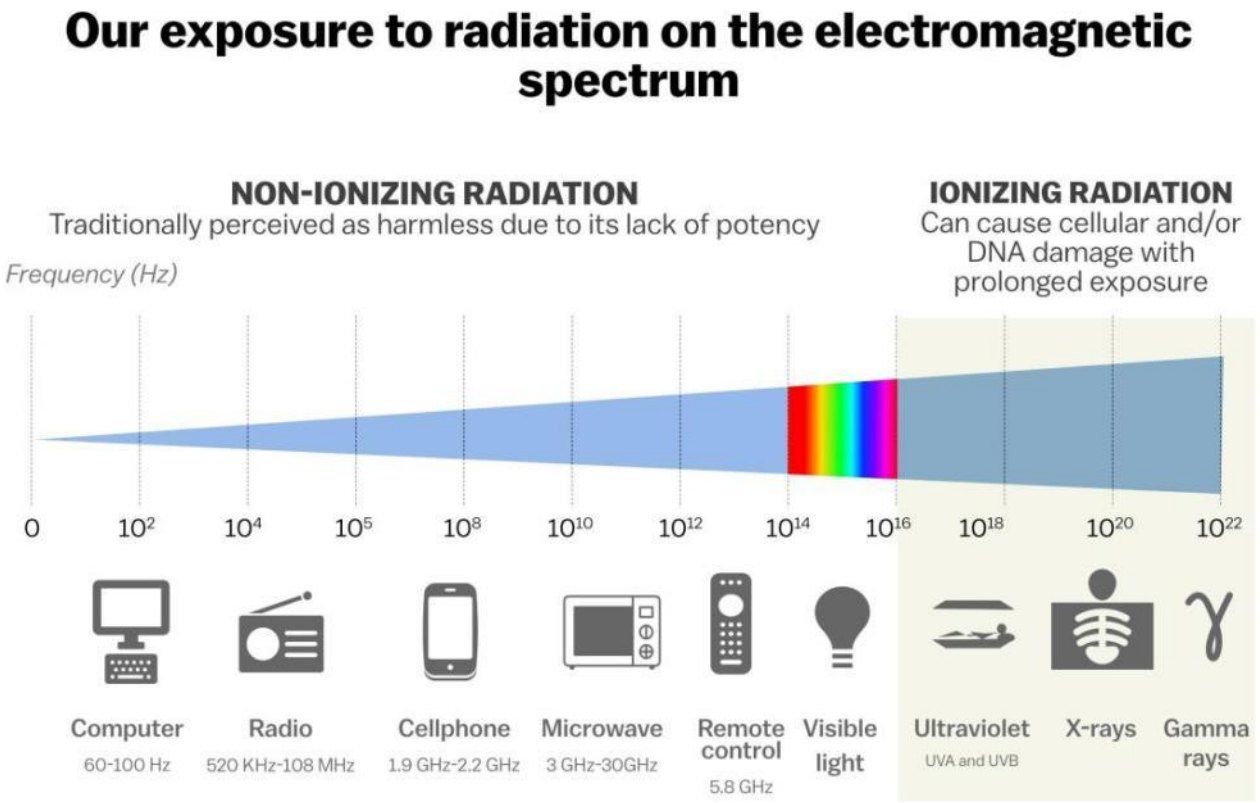
기술분야: 무선통신, 이동통신망, 호처리

이동통신 주파수 대역


5G
6 GHz
24 GHz
100 GHz
4G
Large Millimeter Wave Bandwidth Opportunity

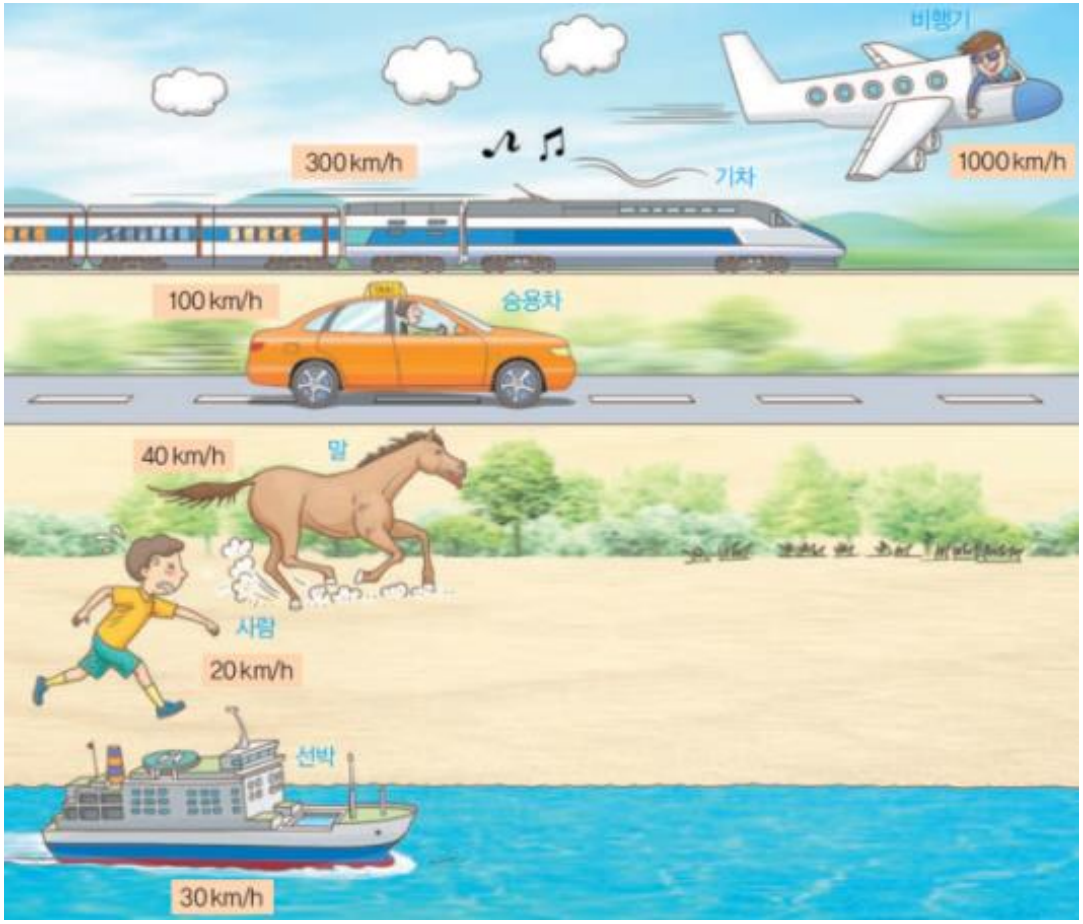

1991
2G
1998
3G
2008
4G
2020?
5G
Texting
Texting
Internet access
Texting
Internet access
Video
Texting
Internet access
Ultra HD & 3-D video
Smart home
2G Frequencies
GSM 2G
Upto 1.9 Ghz
3G Frequencies
HSDPA 3G
Upto 2.1 Ghz
4G Frequencies
LTE 4G
Upto 2.5 Ghz
5G Frequencies
IoT 5G
Upto 95 Ghz

Electromagnetic Spectrum

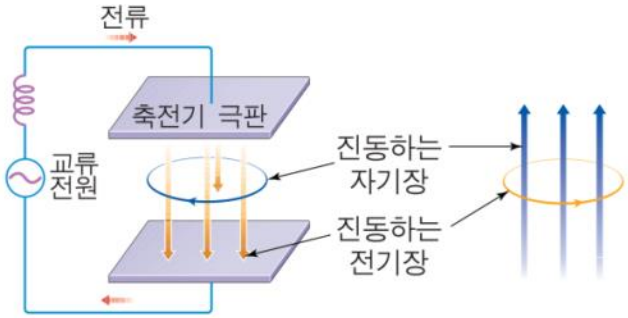


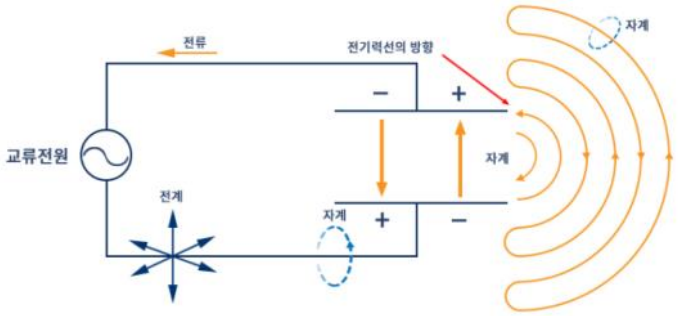
- 전파: 3,000GHz 이하 주파수인 전자파
- 주파수 : 전기장과 자기장의 진동(oscillation)과 같은 주기적 현상이 단위 시간(1초) 동안에 반복되는 횟수

주파수 대역별 특징 비유

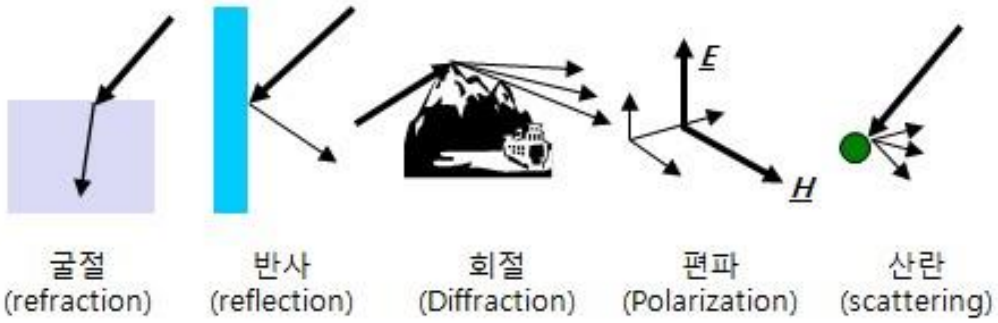


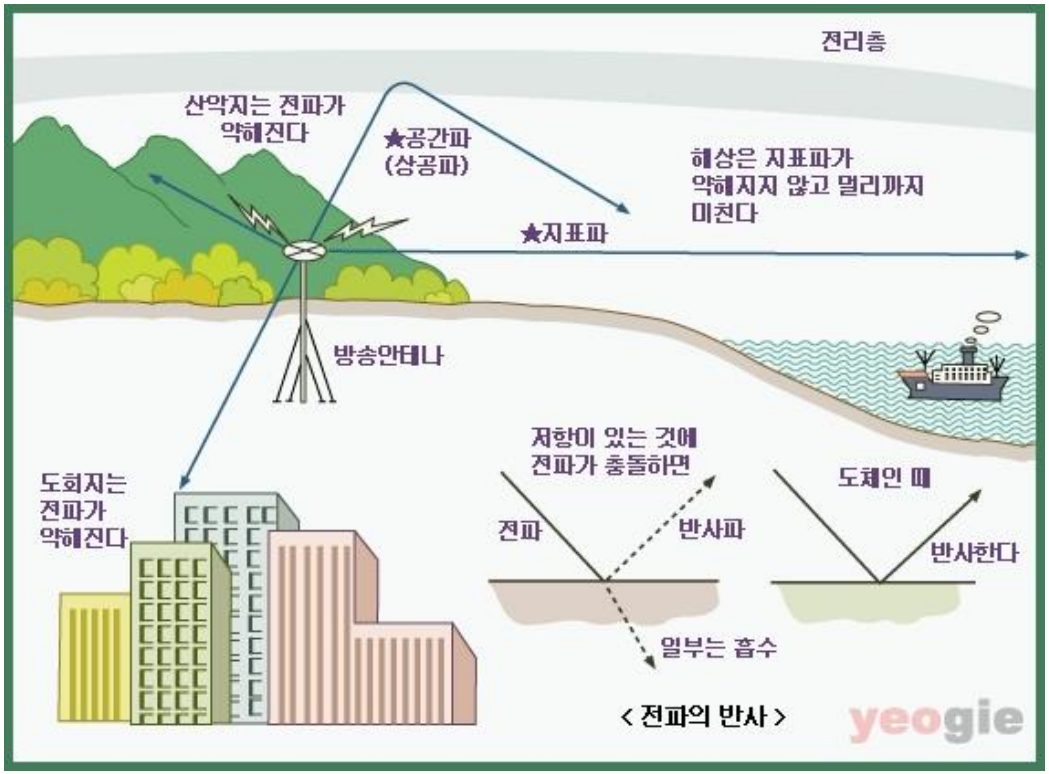
전파의 발생



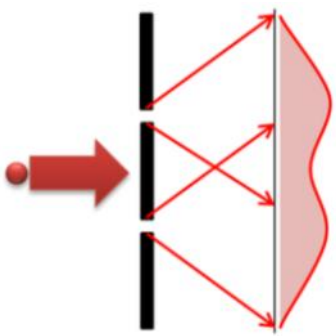


전파의 주요 특징

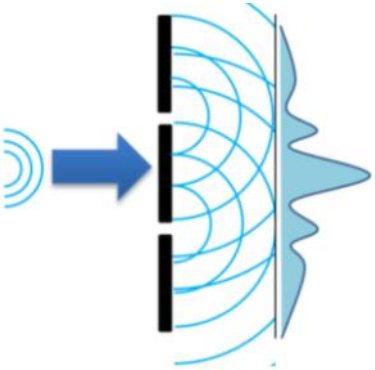

E
H
굴절
(refraction)
반사
(reflection)
회절
(Diffraction)
편파
(Polarization)
산란
(scattering)


전리층
산악지는 전파가
약해진다
★공간파
(상공파)
해상은 지표파가
약해지지 않고 멀리까지
미친다
★지표파
방송안테나
저항이 있는 것에
전파가 충돌하면
전파
반사파
도체인 때
반사한다
일부는 흡수
도회지는
전파가
약해진다
< 전파의 반사 >
yeogie

전파의 회절



입자성질



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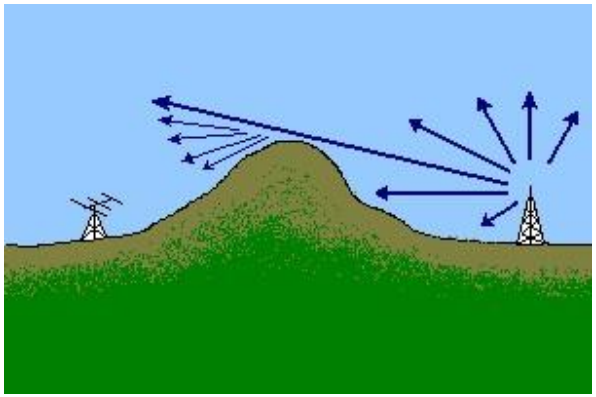
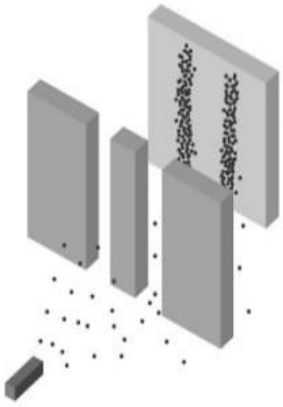
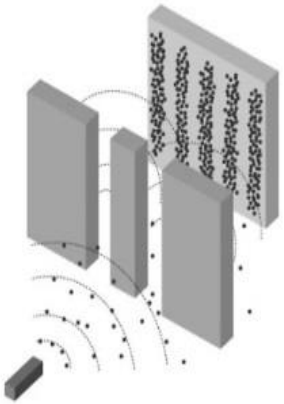
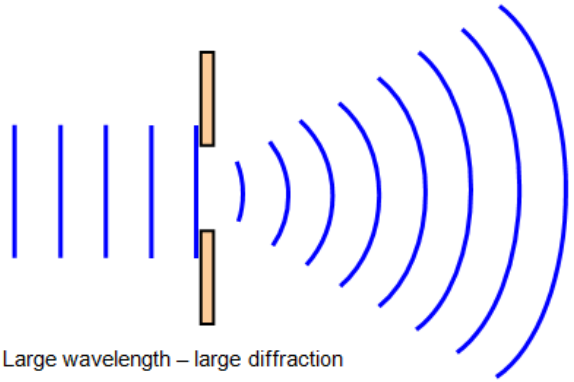
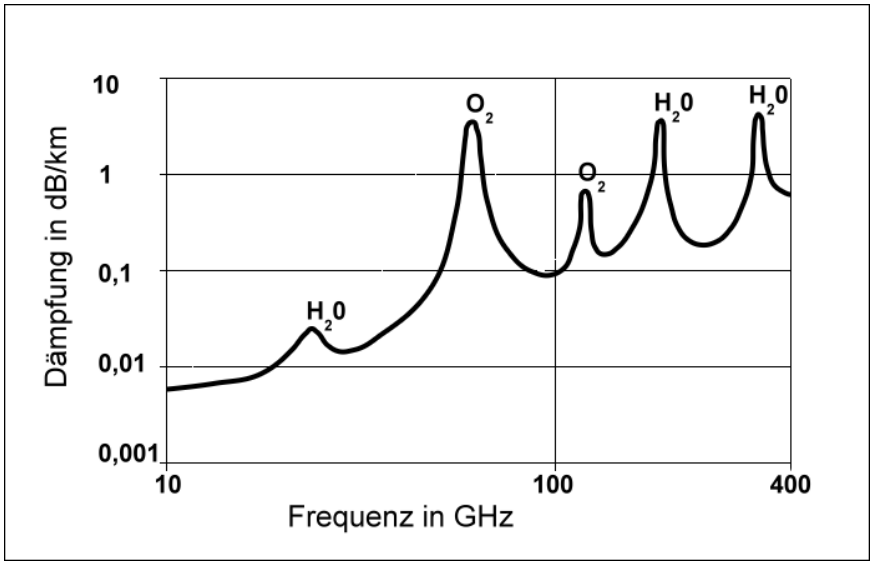


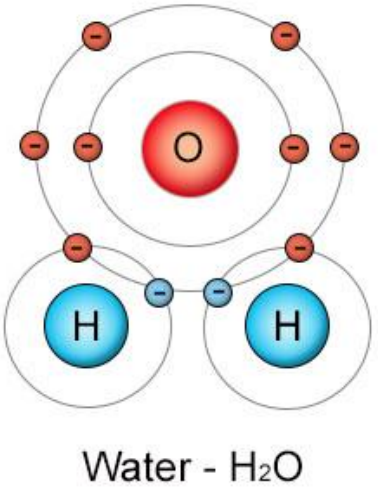


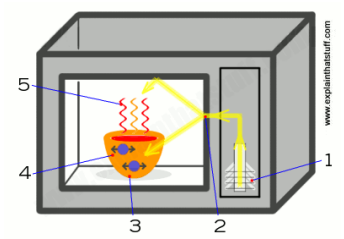


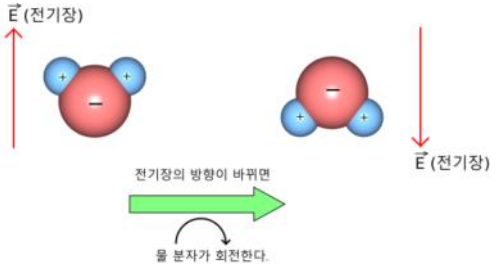


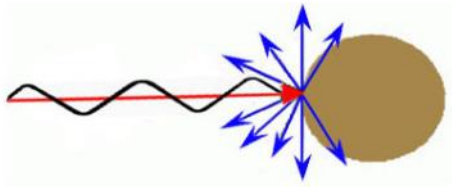
주파수 대역 별 감쇄 정도(1)



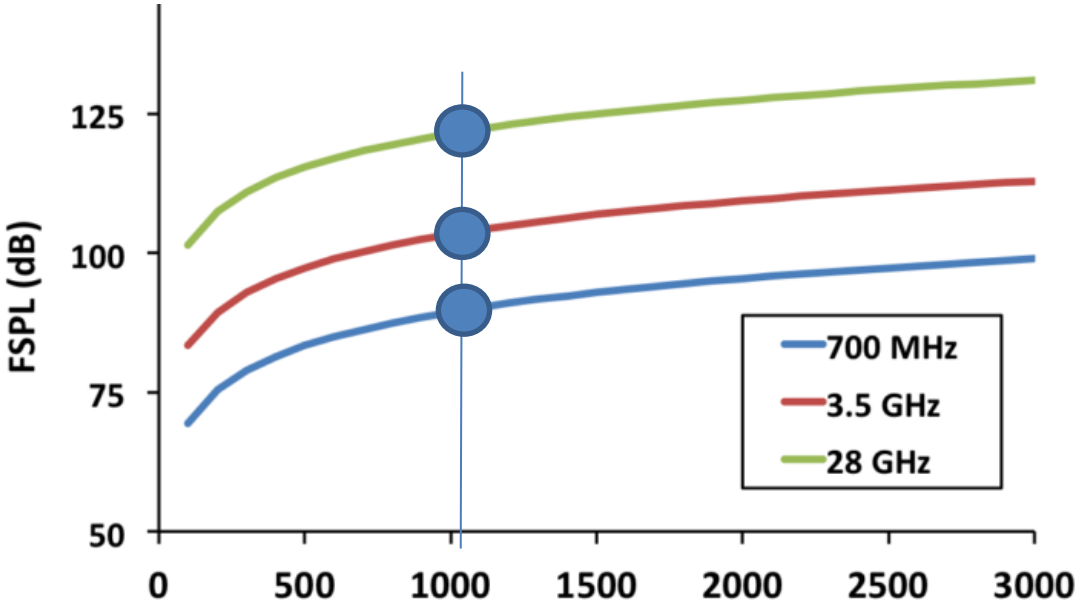




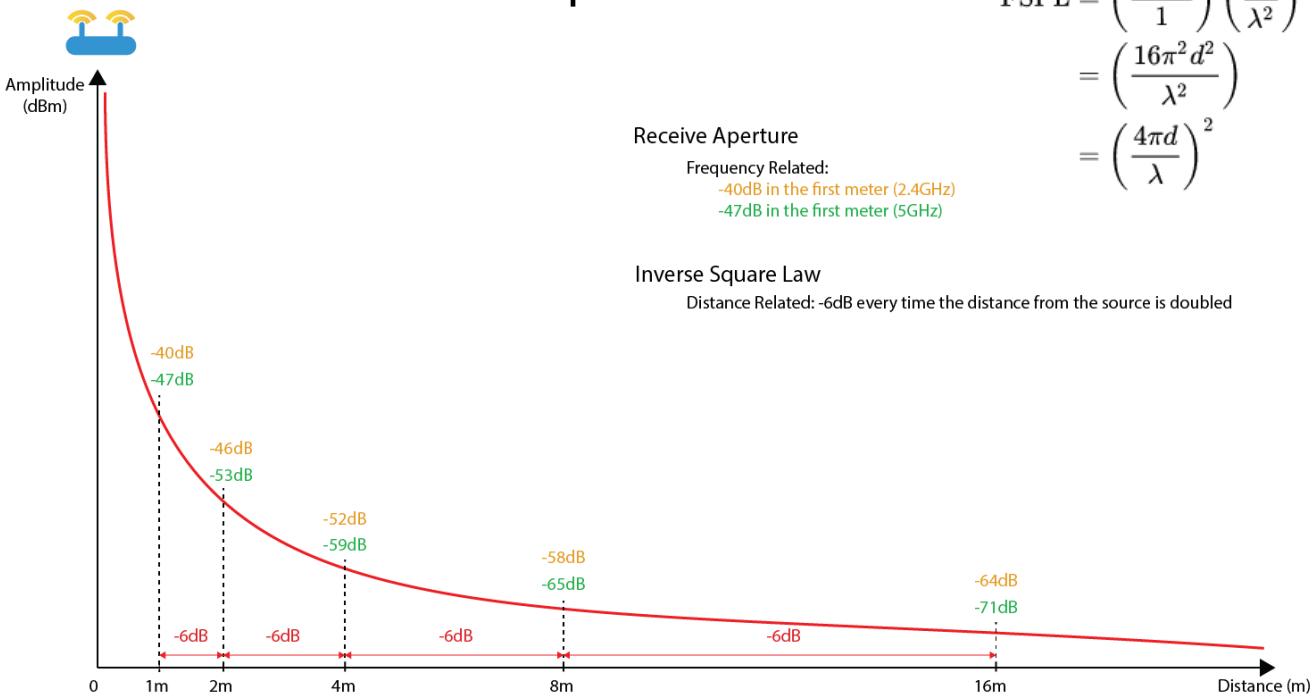




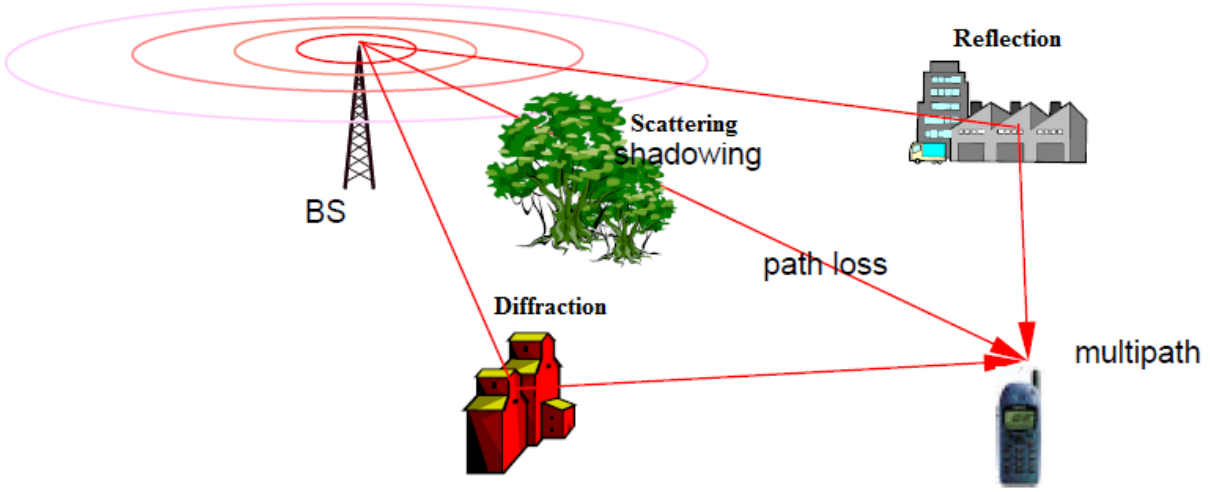
주파수 대역 별 감쇄 정도(2)

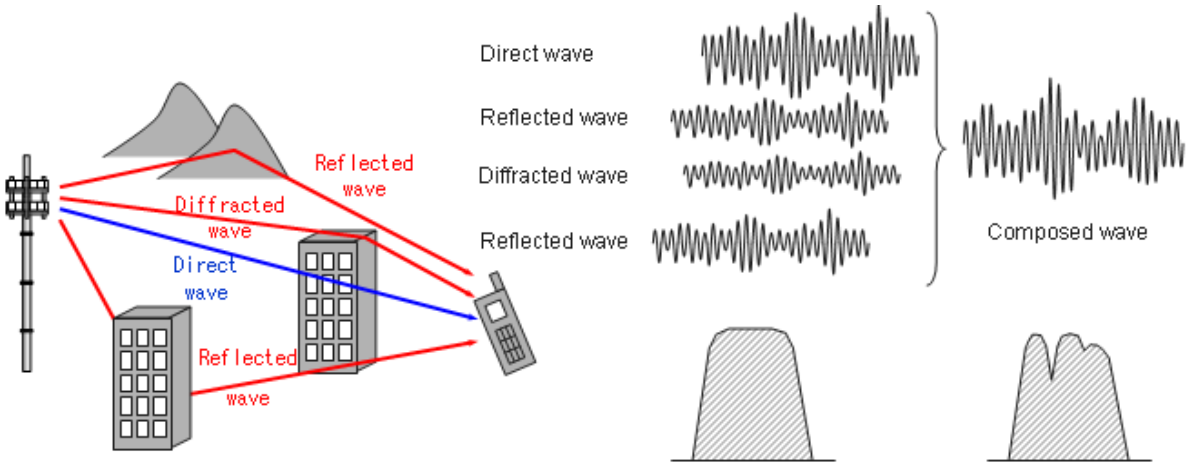


Free Space Path Loss

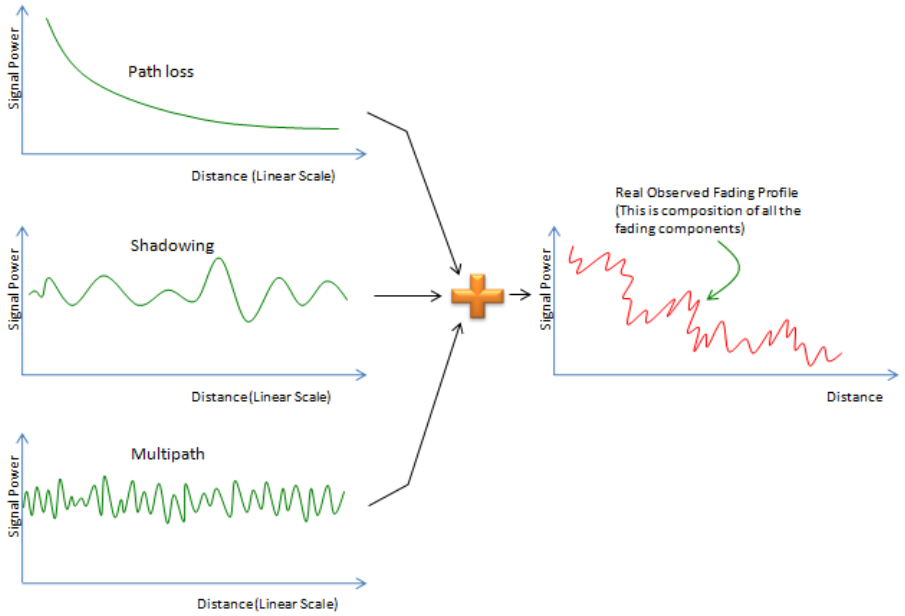


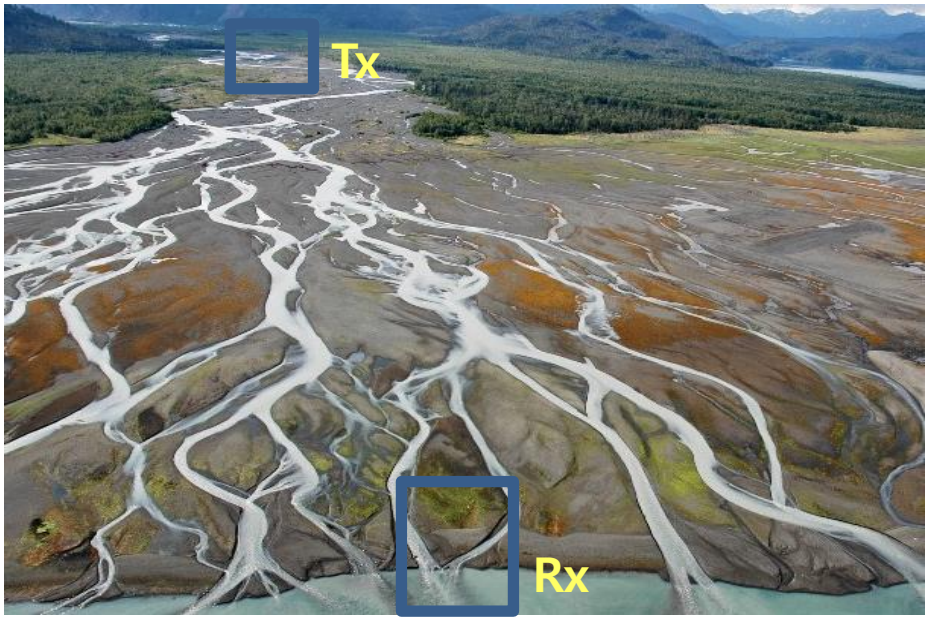
Multipath Fading(1)



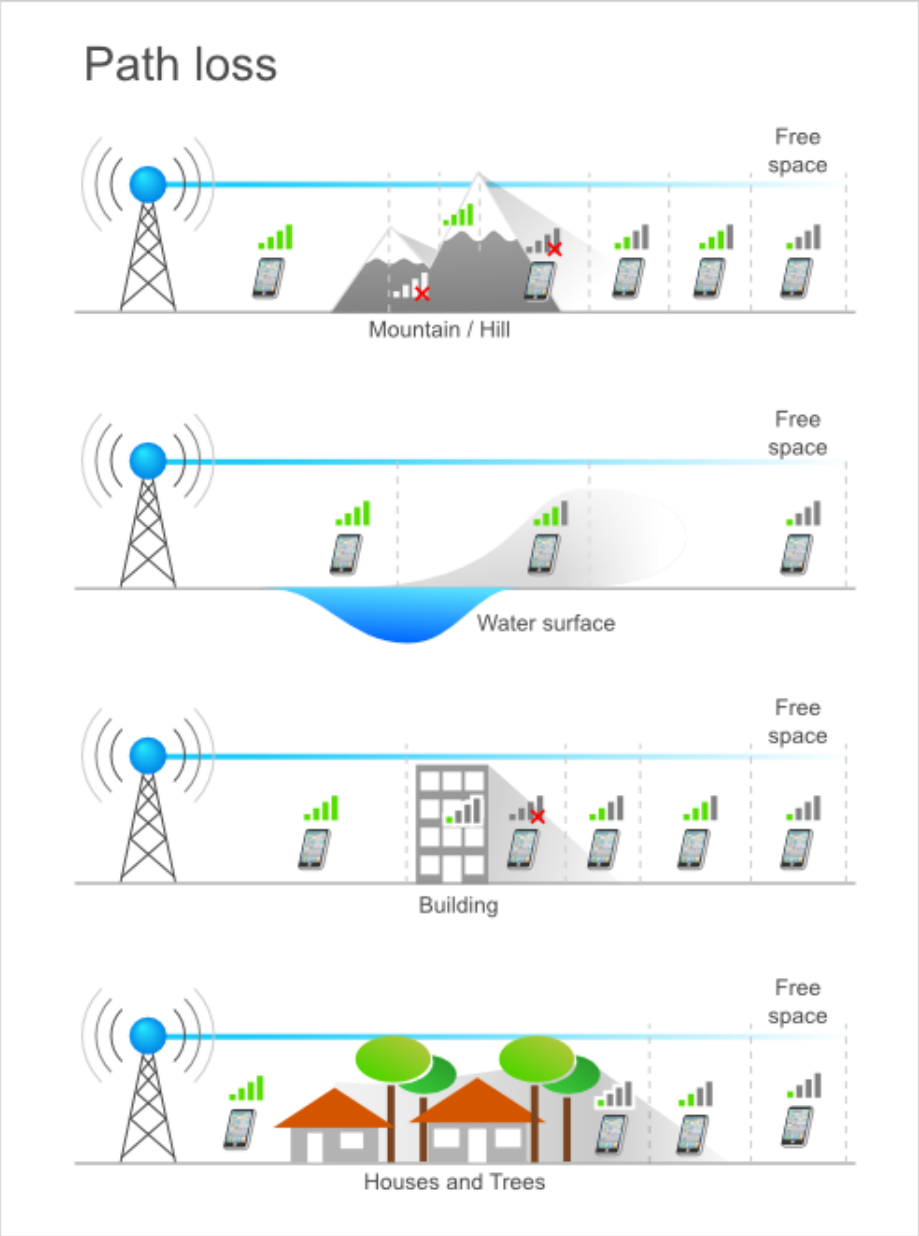


Multipath Fading(2)

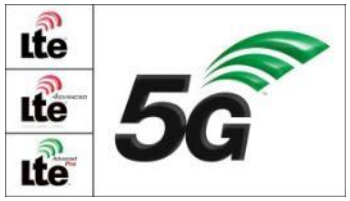




지형별 Path Loss 예



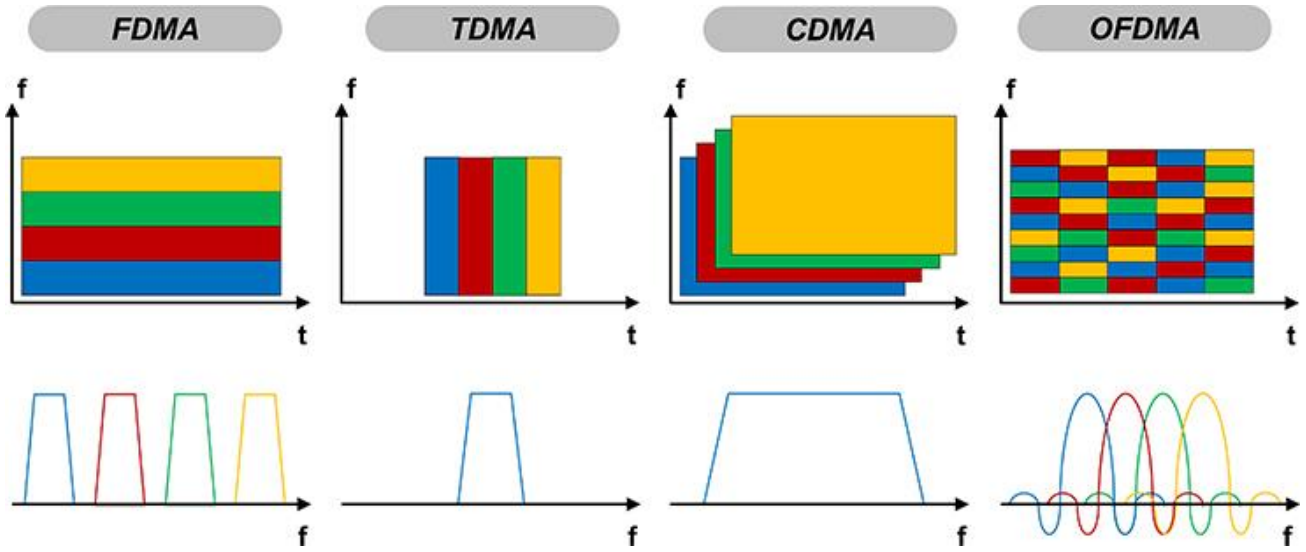
무선통신 주파수(사용목적에 따라)



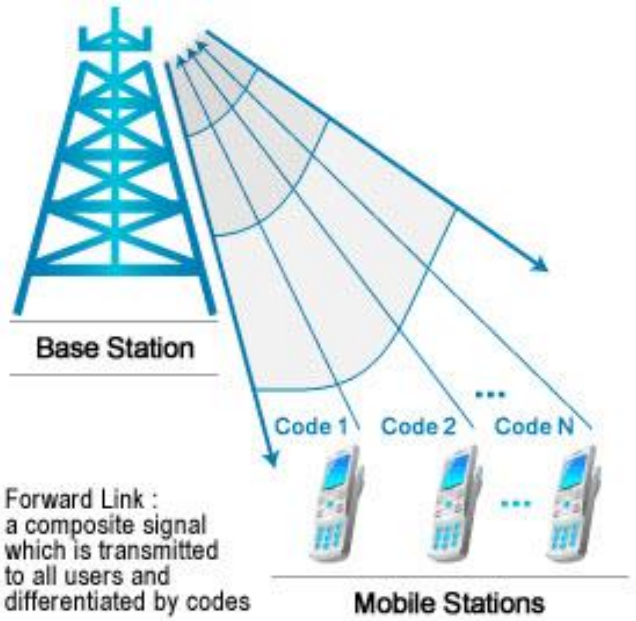
Multiple Access

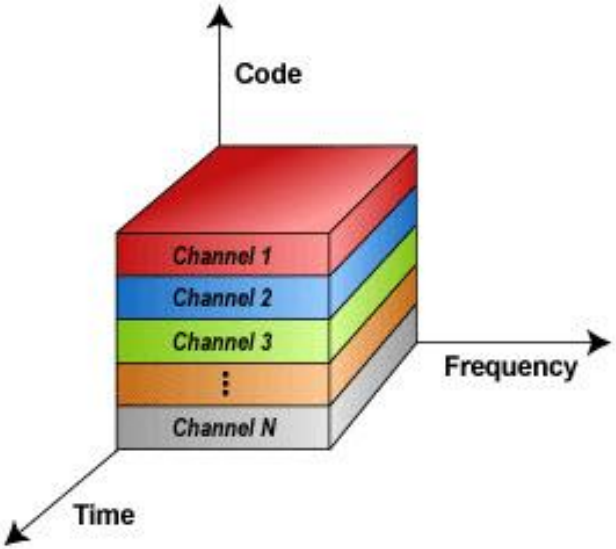
Multiple Access Technologies

Multiple access *is a technique that lets multiple mobile users share the allotted spectrum in the most effective manner.*

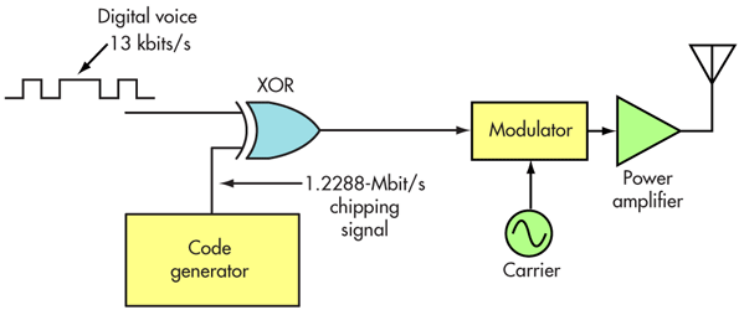


CDMA: Code Division Multiple Access

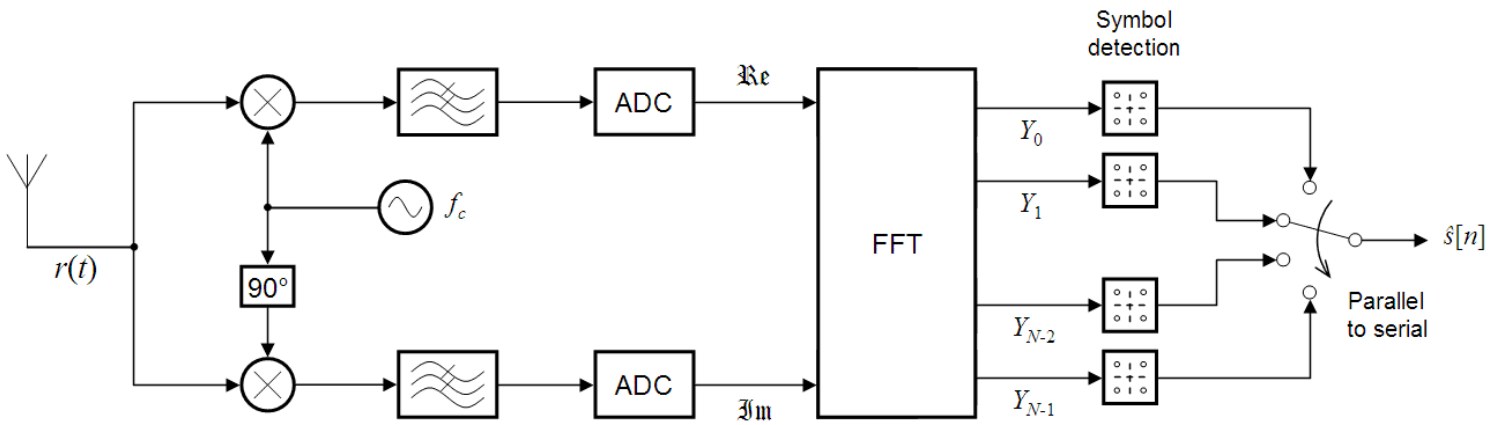


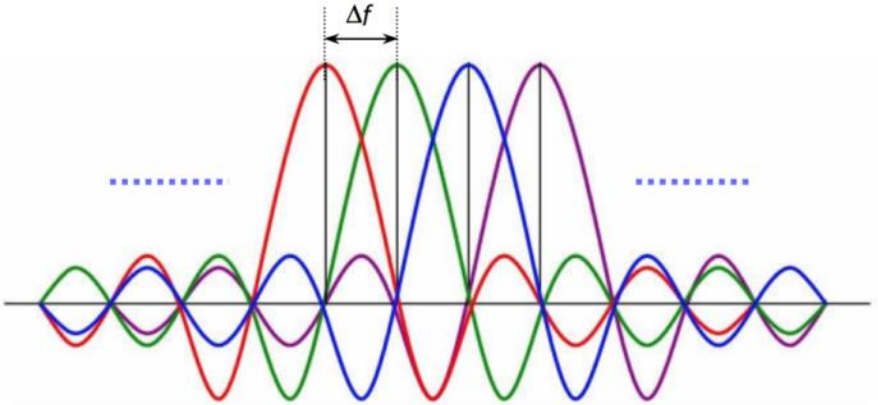


CDMA in which each channel is assigned a unique code which is orthogonal to codes used by other users.



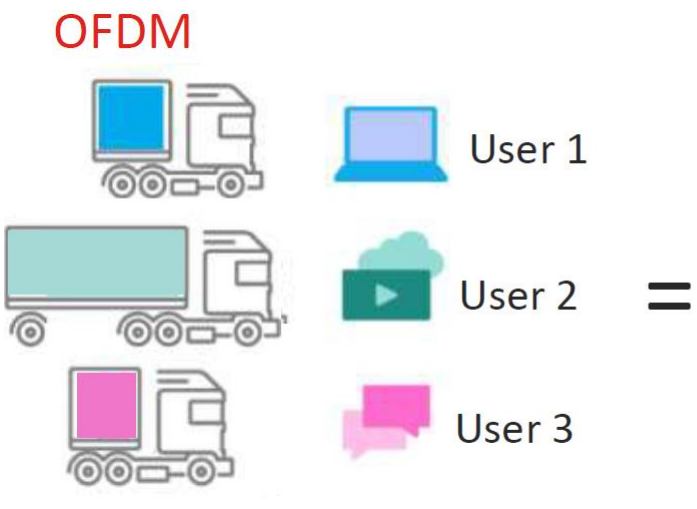
OFDM: Orthogonal Frequency Division Multiplexing





* OFDM 최초 개발: Bell Labs(1966)

OFDM vs. OFDMA



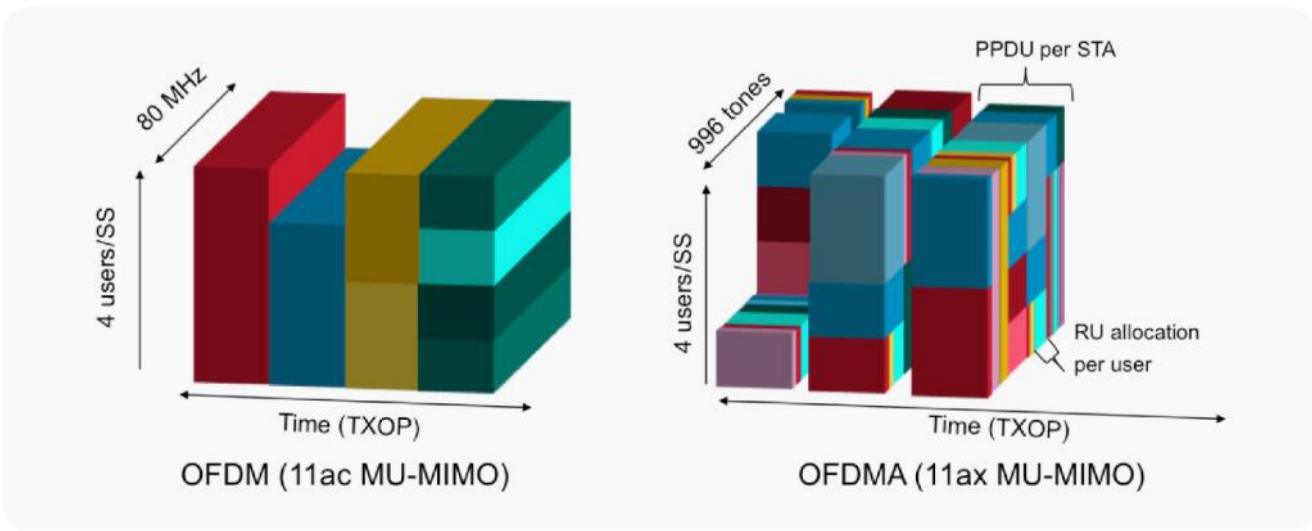
=

=

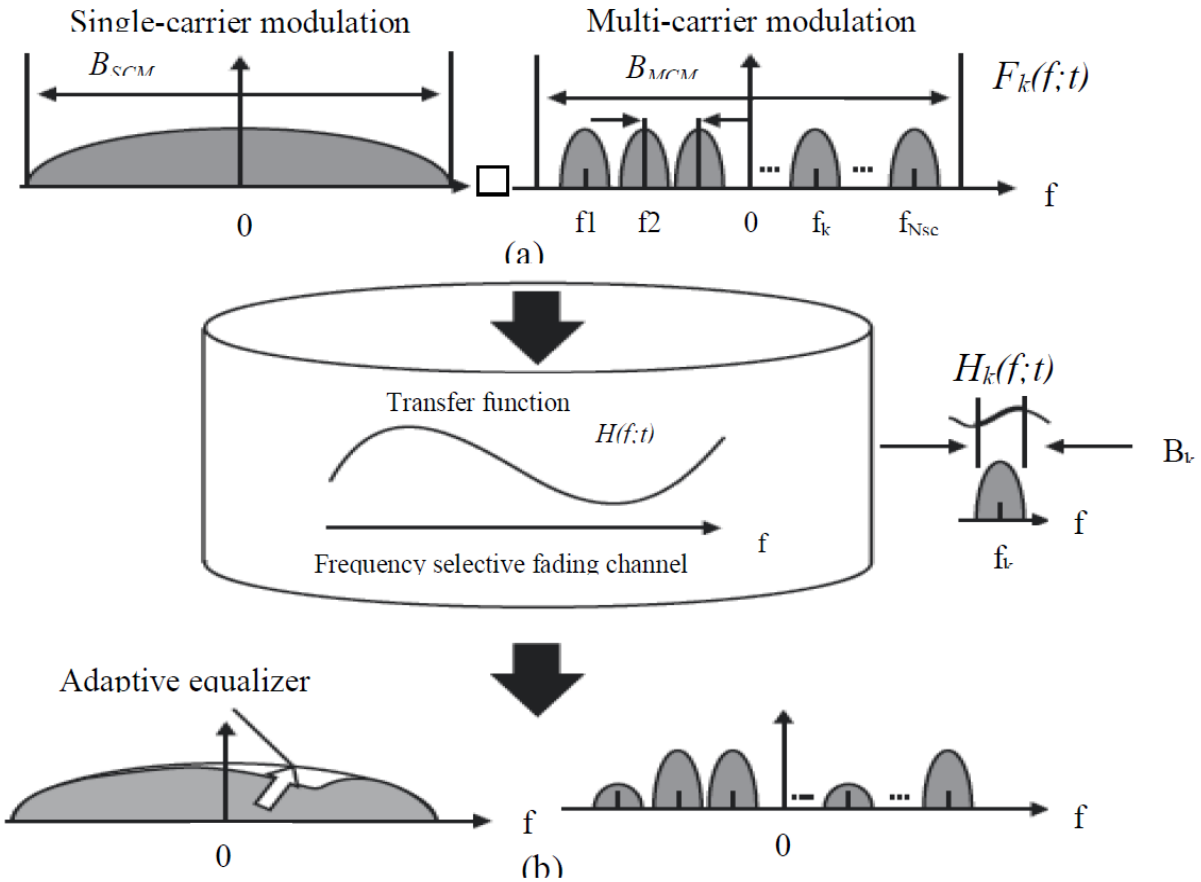
OFDMA 비유


사용자 A
사용자 B
사용자 C


IoT A
IoT B
Data Push

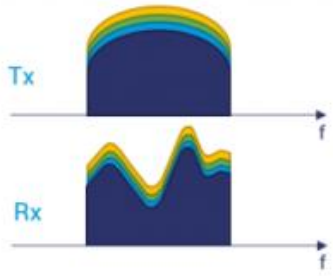

80 MHz
4 users/SS
Time (TXOP)
OFDM (11ac MU-MIMO)
PPDU per STA
996 tones
4 users/SS
RU allocation
per user
Time (TXOP)
OFDMA (11ax MU-MIMO)

ISI(Inter Symbol Interference) - 1



ISI(Inter Symbol Interference) - 2

2 options for transmitting the data



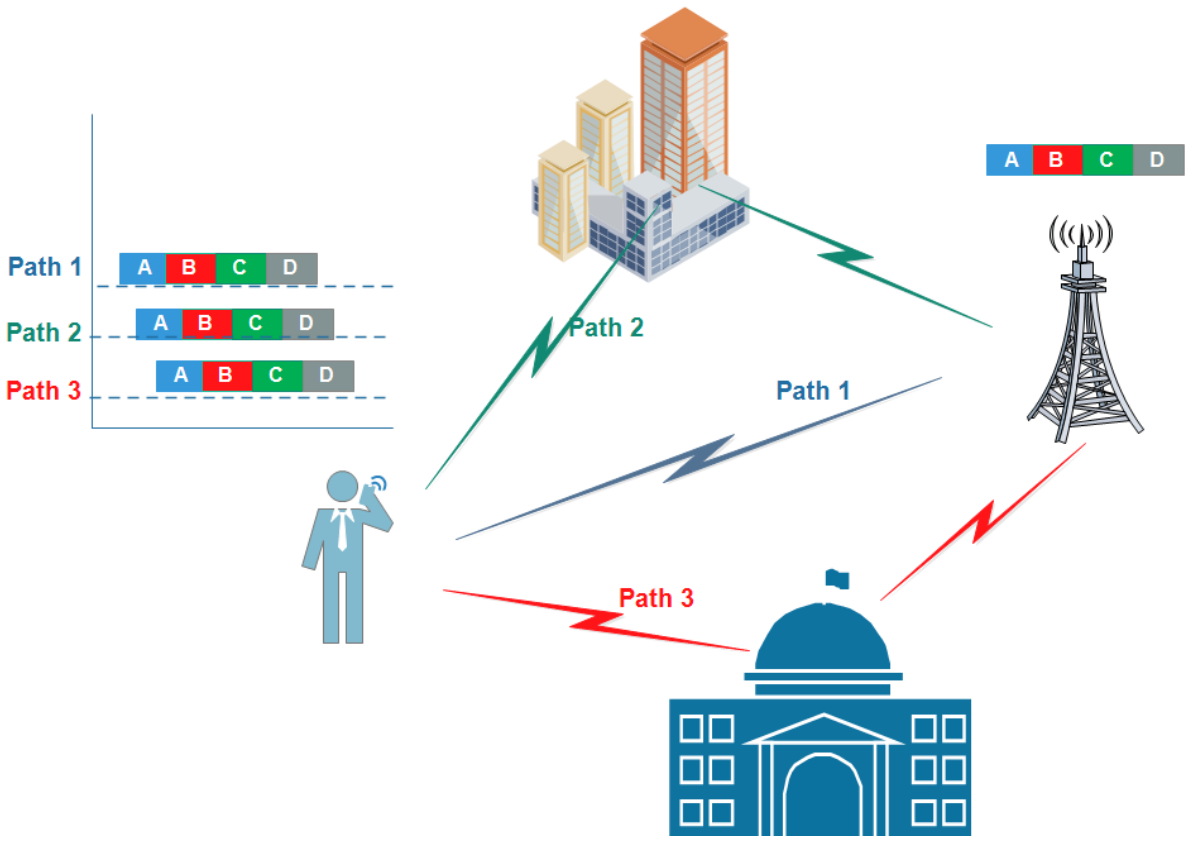
Both cary the same date but a deep fade damages only 1/4 of data

2 options for shipment goods via a truck

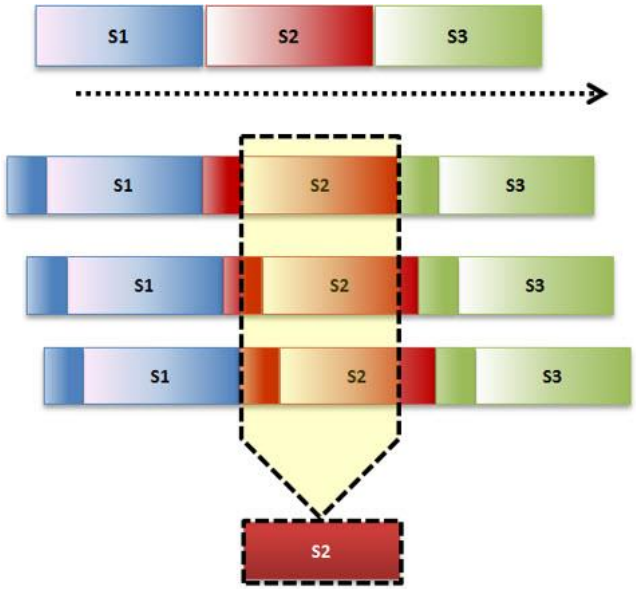
Both carry the same goods, but an accident damages only 1/4 of goods

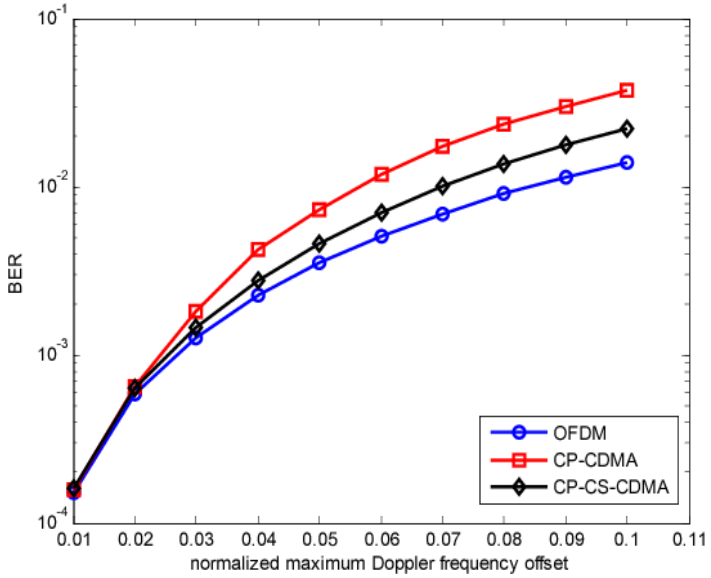
GRANDMETRIC WATCH

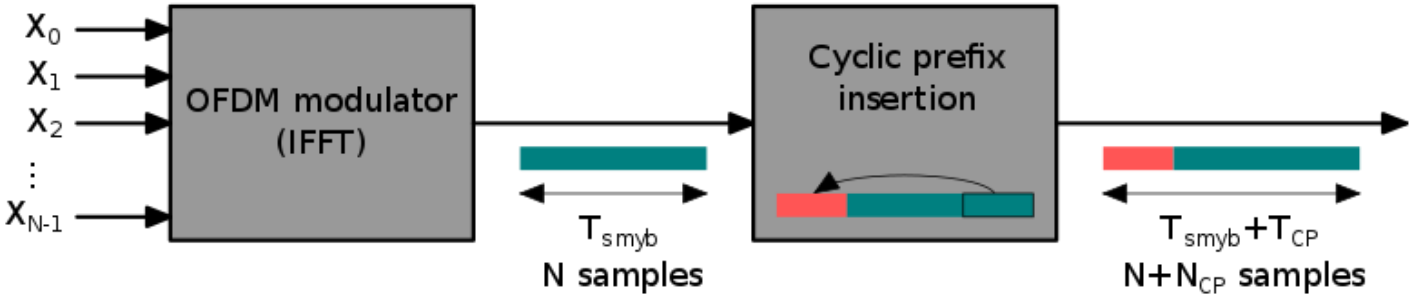
Delay Spread



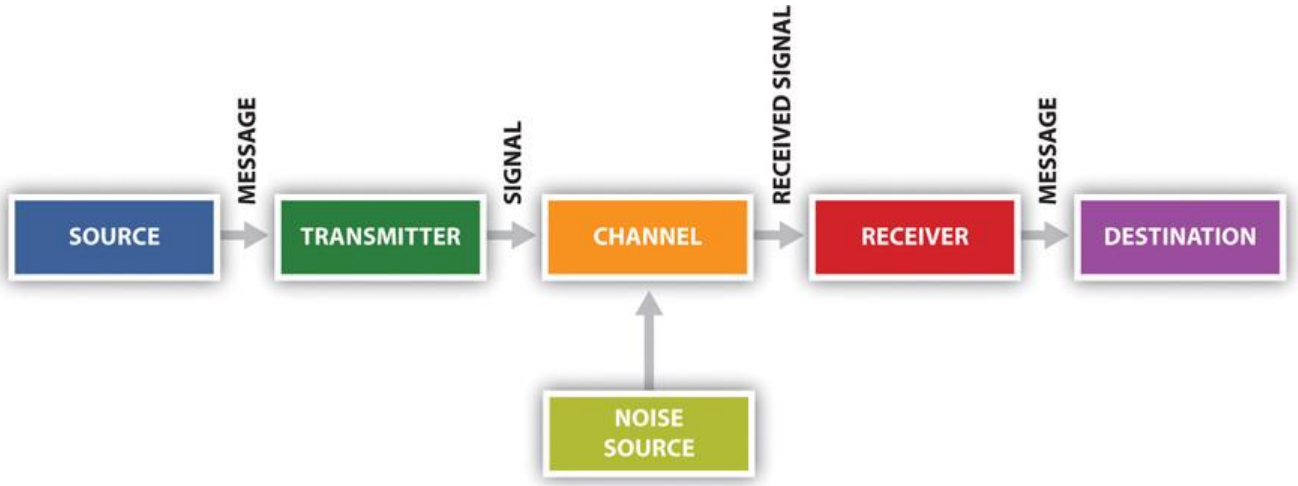
Delay Spread 극복방법 – Cyclic Prefix







Shannon's Law – Channel Capacity



Capacity =
Maximum achievable
data rate (in bits/sec)

$$C = B \cdot \log_2(1 + \frac{S}{N})$$

Signal Power
(in Watts)

Noise Power
(in Watts)

SNR (Linear Scale, not in dB)

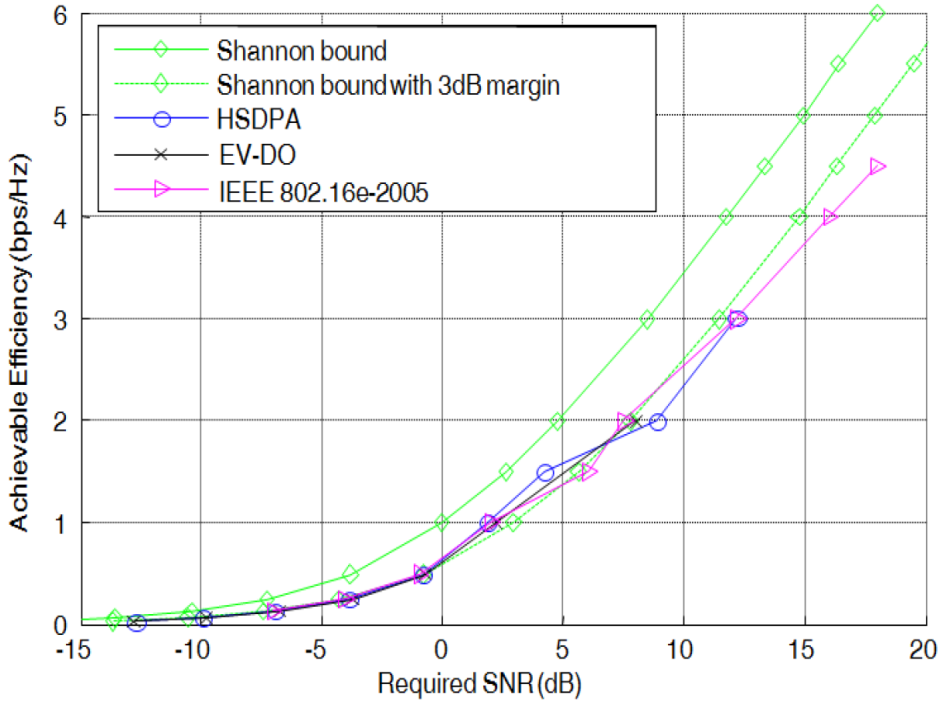
As this gets larger, C (Capacity)
gets larger

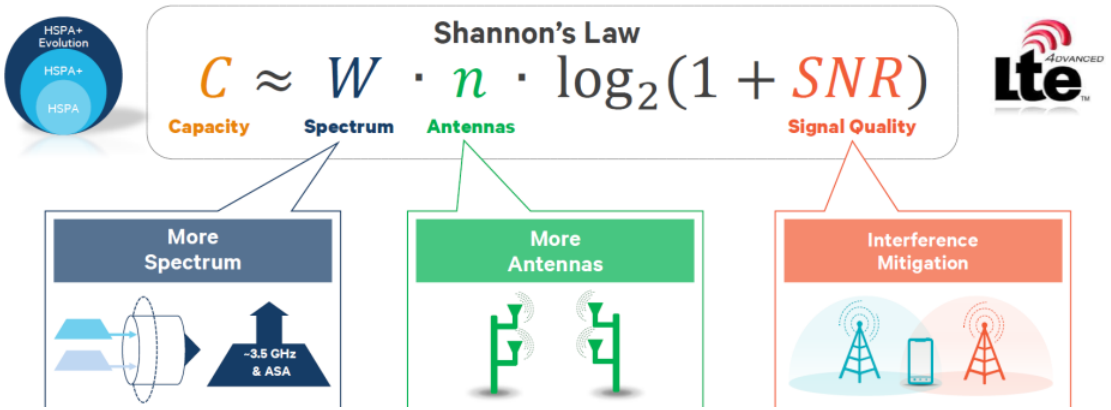
Ex >
With Diversity, you can increase
this value

Radio Channel Bandwidth
(in Hz)

As this gets larger, C (Capacity)
gets larger

Shannon's Law 한계치에 도달

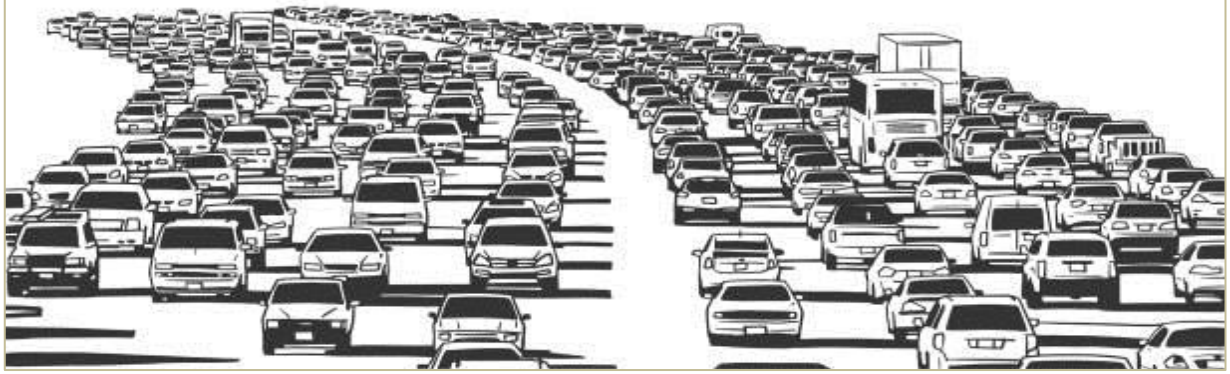




Channel Capacity 늘이는 방법

4G

Shannon 한계치에 도달



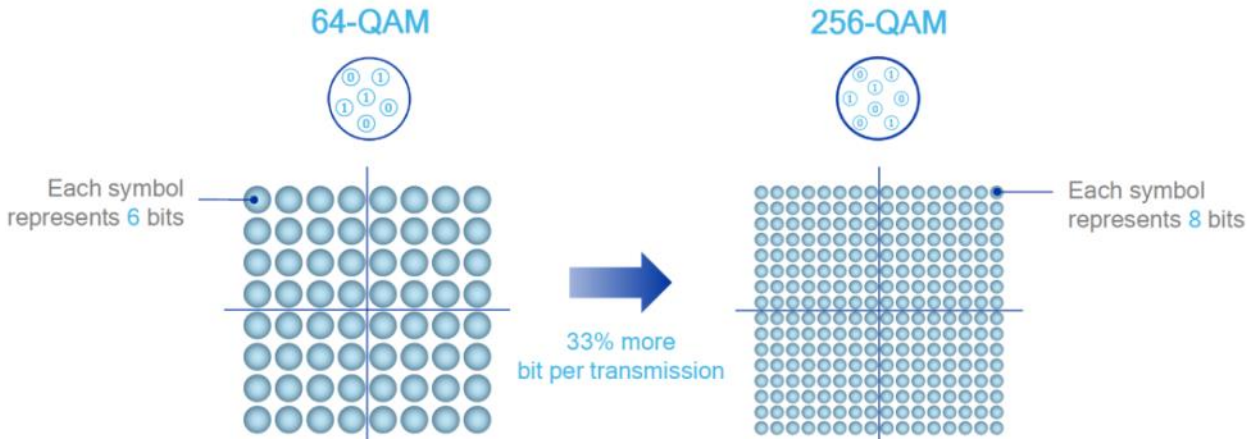
5G

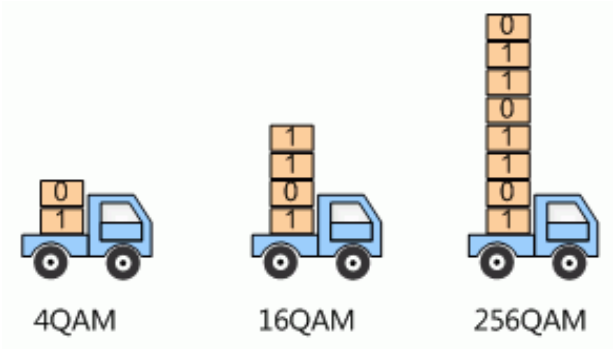
새로운 도로 구축

+

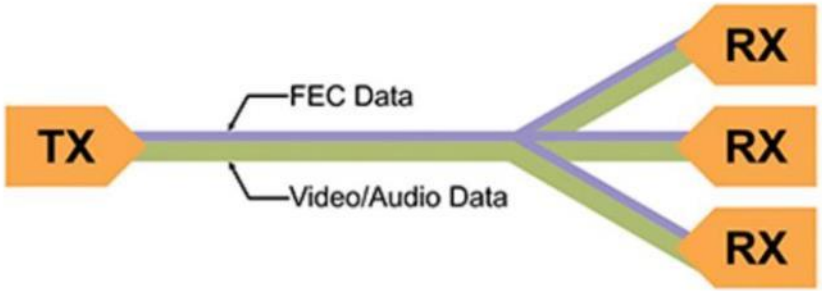
고가도로 구축

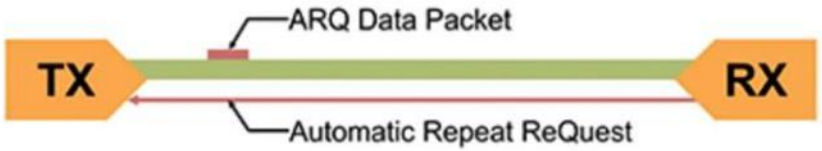
* QAM(Quadrature Amplitude Modulation)

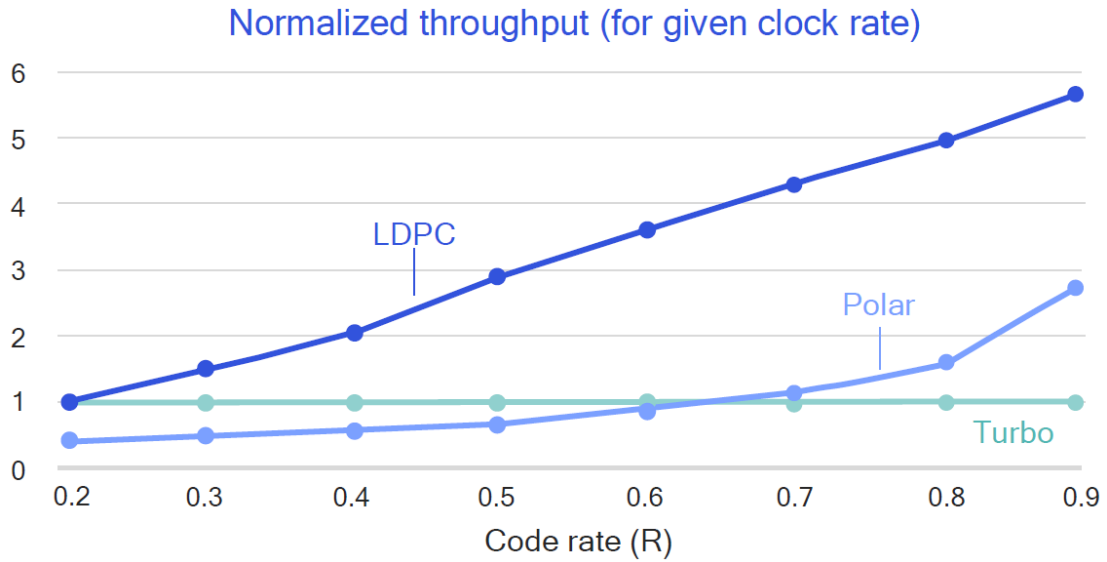




* Channel Coding

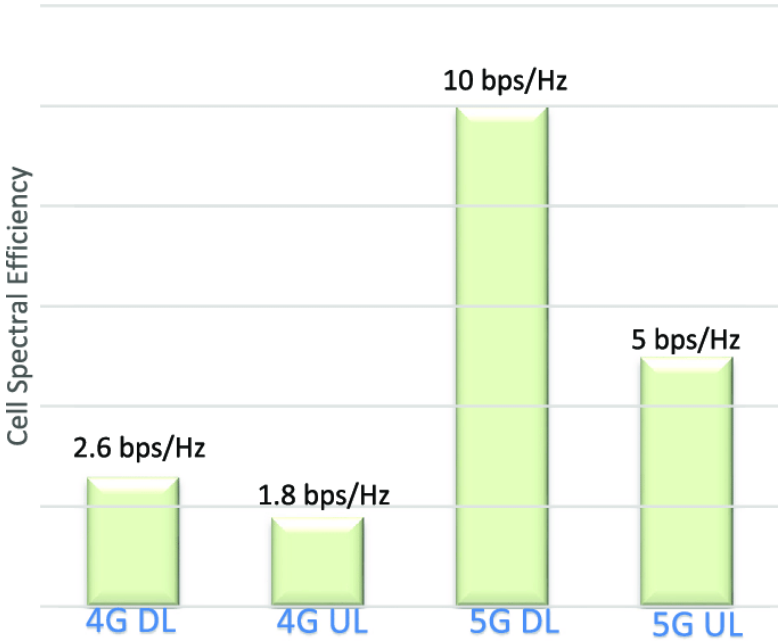


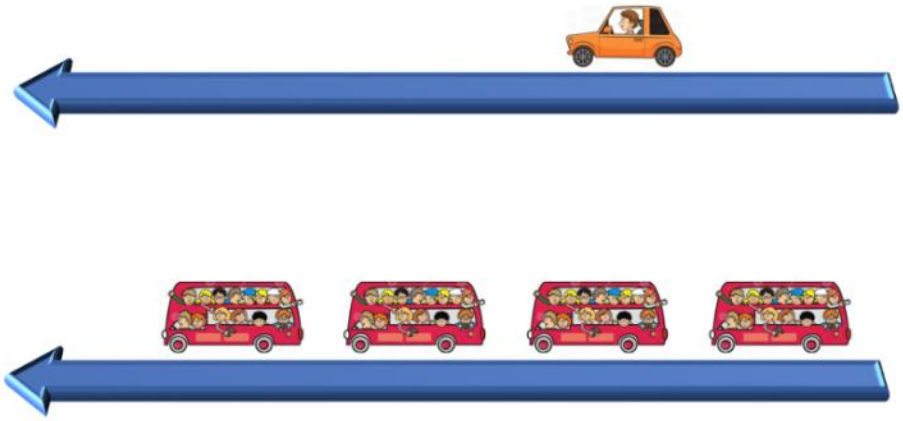




* LDPC: Low Density Parity Check
  - 5G eMBB CH
* Polar Code: 5G Control CH

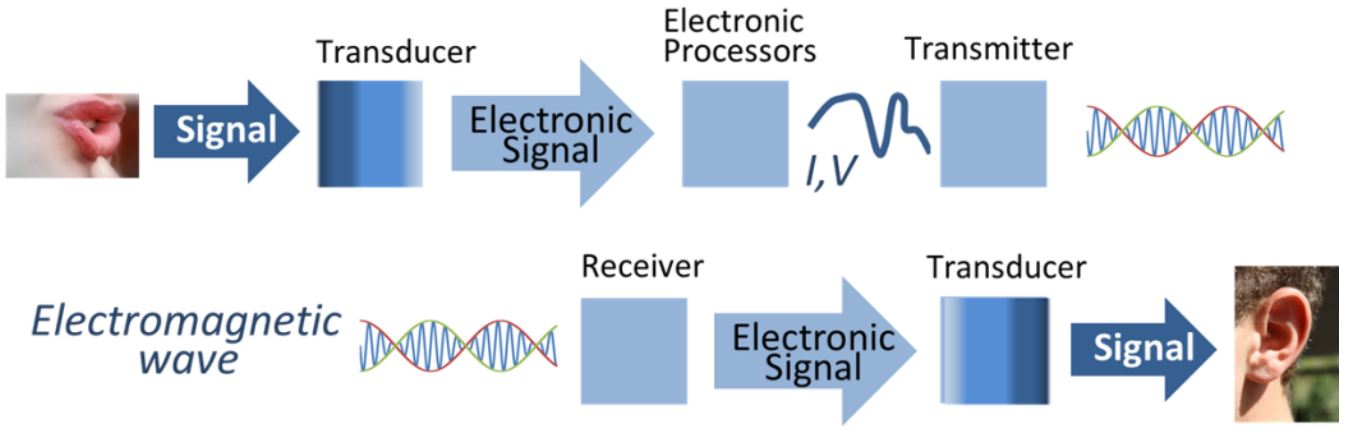
* Special Efficiency

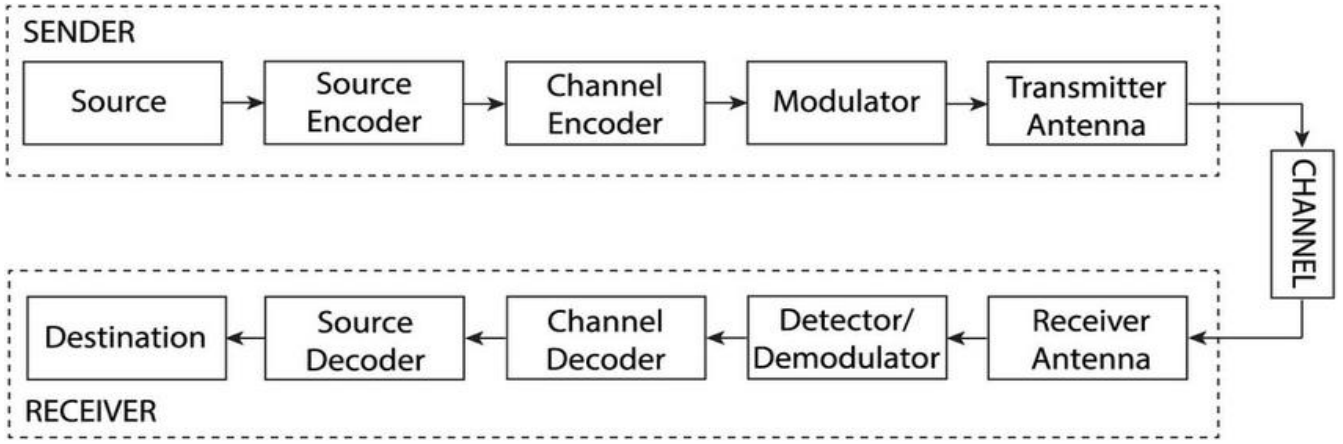




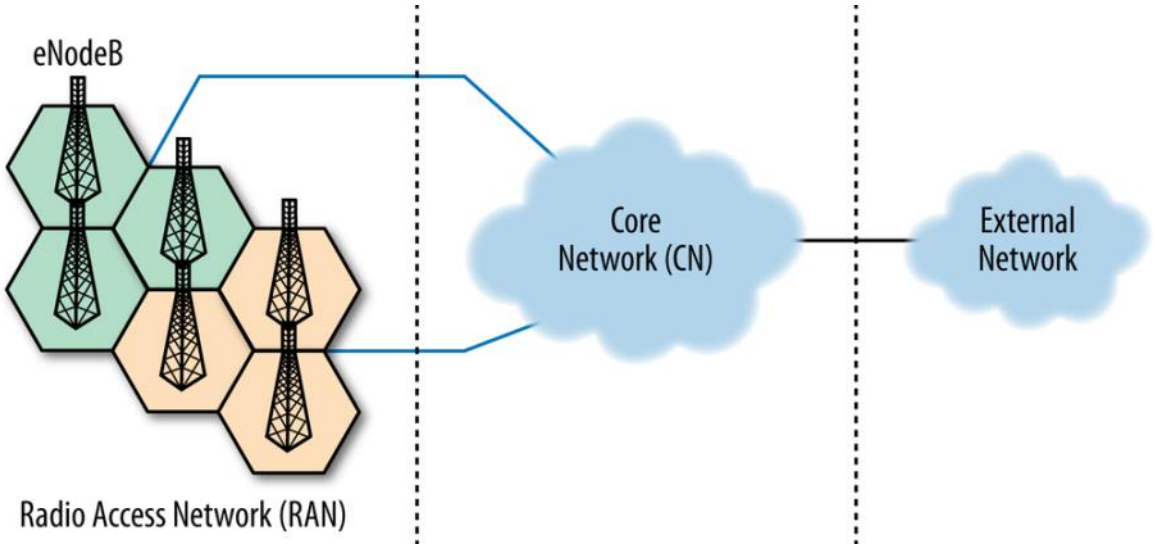
이동통신망 구조

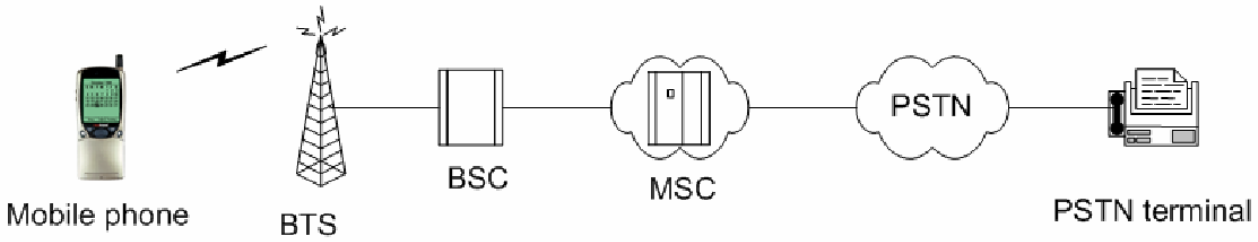
무선통신 신호처리 절차


Transducer
Electronic Processors
Transmitter
Signal
Electronic Signal
I,V
Receiver
Transducer
Electromagnetic wave
Electronic Signal
Signal


SENDER
Source
Source Encoder
Channel Encoder
Modulator
Transmitter Antenna
CHANNEL
Destination
Source Decoder
Channel Decoder
Detector/ Demodulator
Receiver Antenna
RECEIVER

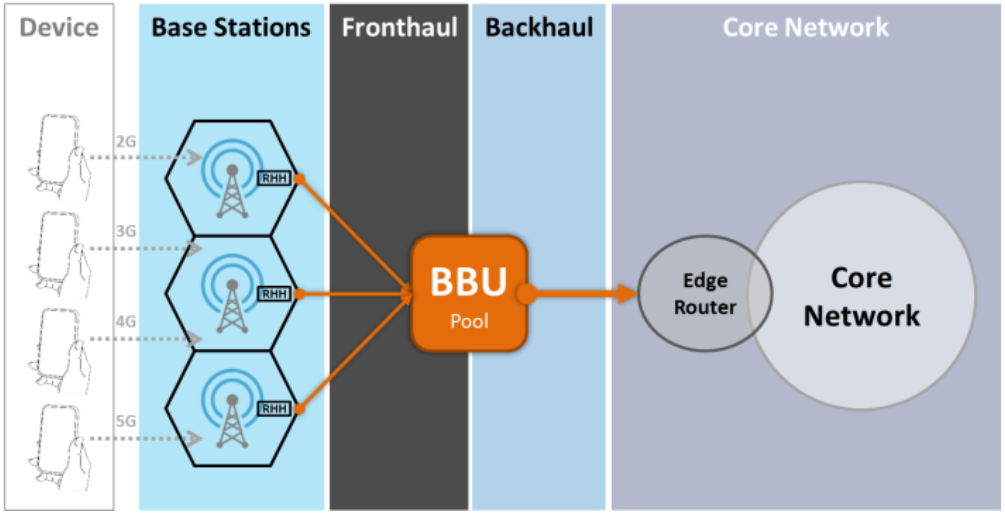
이동통신망 구성도(1)





BTS : Base Transceiver Station
BSC : Base System Controller
MSC : Mobile Switching Center
PSTN : Public Switched Telephone Network

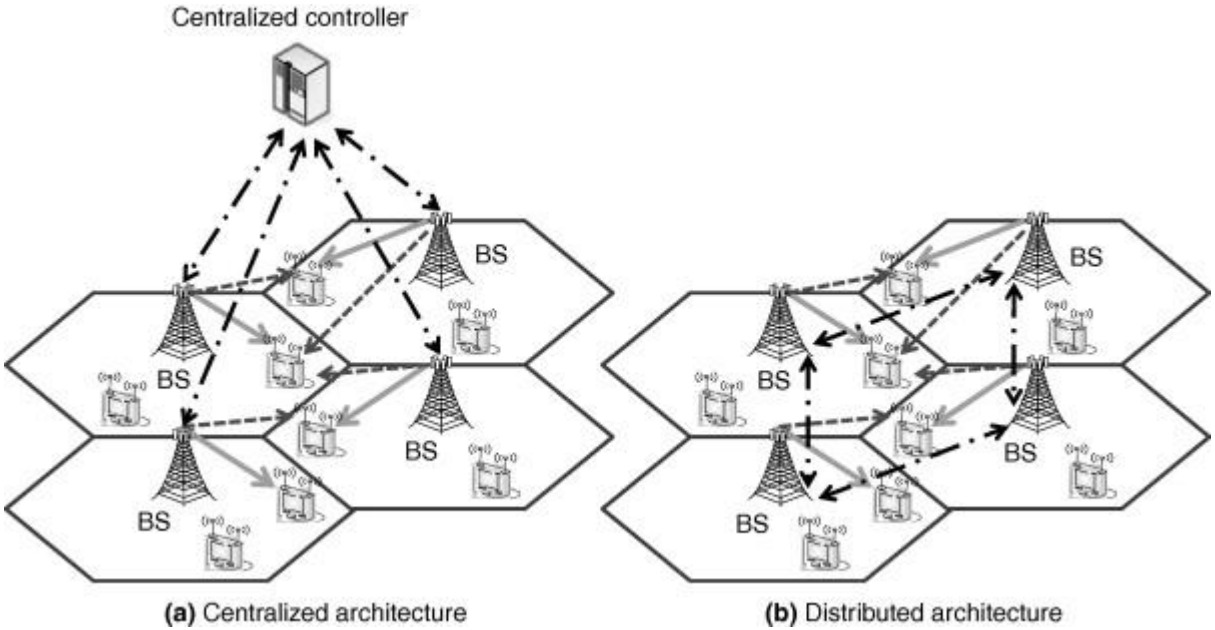
이동통신망 구성도(2)



- 이동통신망은 크게 코어망(Core Network)과 기지국(Base Station)으로 구성됨
  - 코어망은 IP 데이터 처리, 각종 호처리(등록, 인증, 로밍, 과금 등) 처리
  - 기지국은 코어망 정보를 RF로 변환하여 단말기로 전송

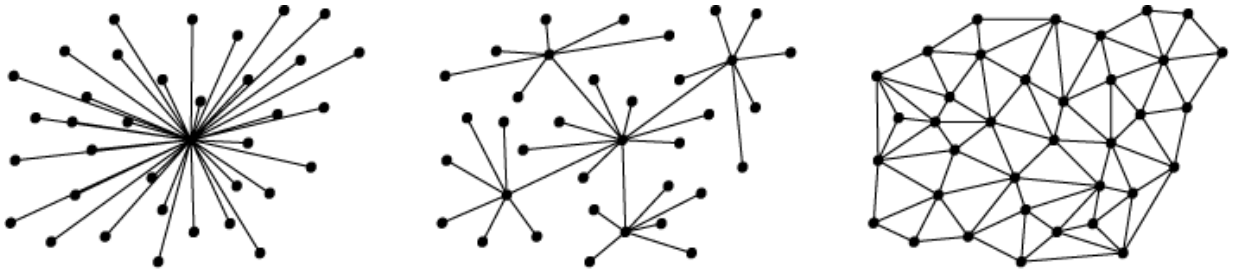
- 코어망에는 SDN(Software Defined Networking, NFV(Network Function Virtualization) 등이 적용되는 추세
  - SDN은 Control Data와 User Data 분리, NFV는 가상화로 다양한 기능 구현
- 기지국은 신호처리부분과 RF를 분리하여 Cloud RAN(Radio Access Network) 추세

Centralized, Decentralized, Distributed Architecture



(a) Centralized architecture

(b) Distributed architecture



centralised

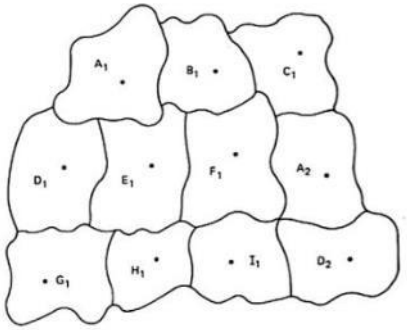
decentralised

distributed

이동통신 기술 시작 - AMPS

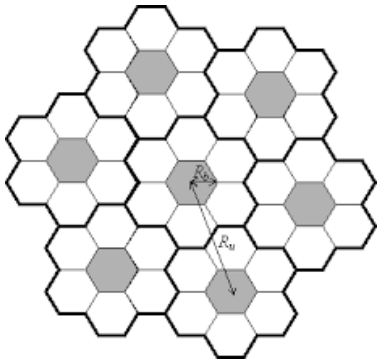
AT&T Bell Laboratories

NOKIA Bell Labs



Q_i : / TH CELL USING CHANNEL SET Q
• : TRANSMITTER LOCATION

Fig. 1—Cellular layout illustrating frequency reuse.



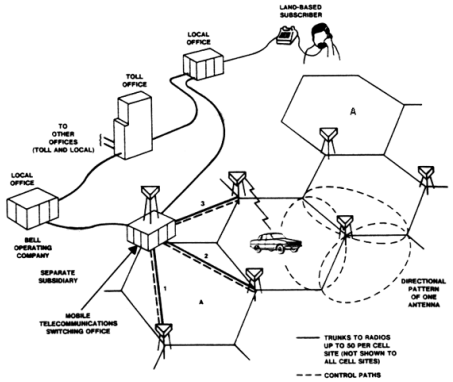
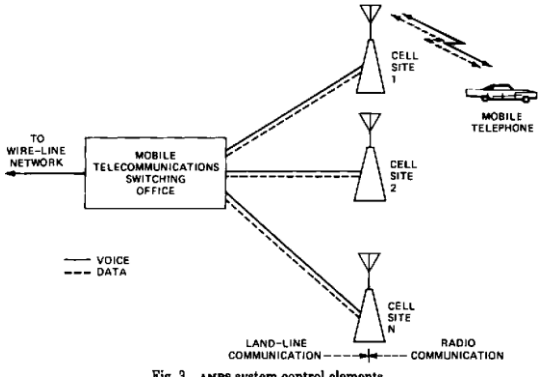
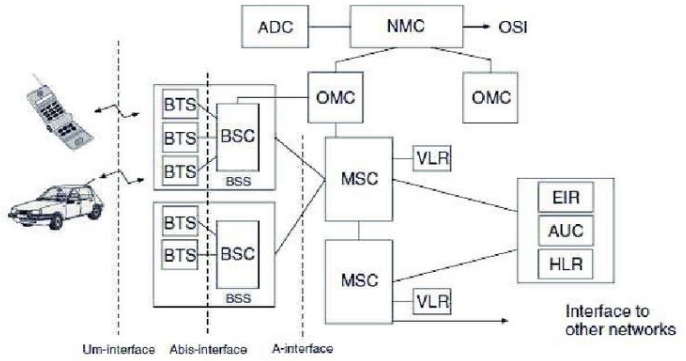


Figure 11-35. Advanced Mobile Phone Service system plan.





이동통신 특징

1

Licensed Spectrum

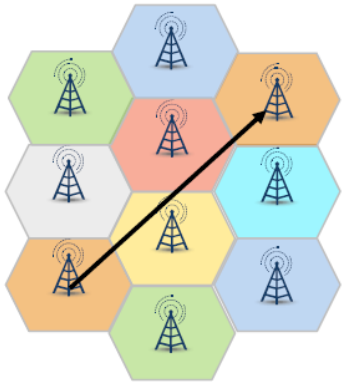
Cleared spectrum for exclusive use by mobile technologies

Operator-deployed **base stations** provide access for subscribers

2

Frequency Reuse

Reusing frequencies without interference through geographical separation

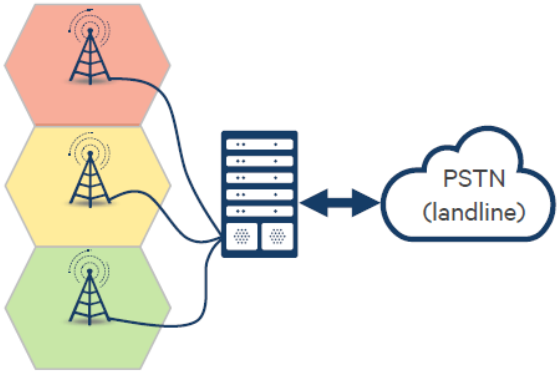


Neighboring **cells** operate on different frequencies to avoid interference

3

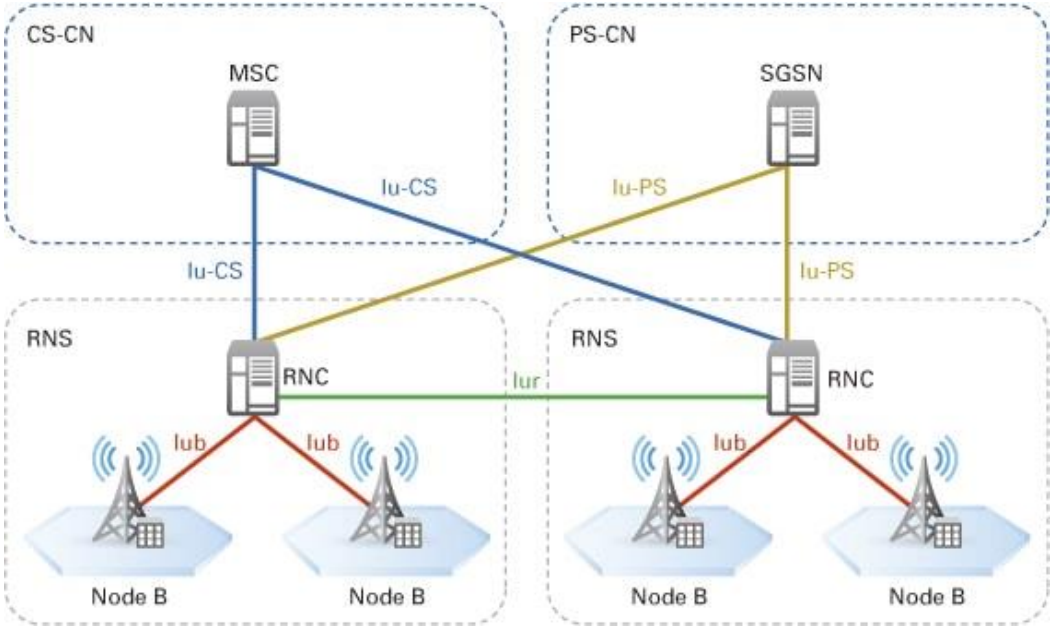
Mobile Network

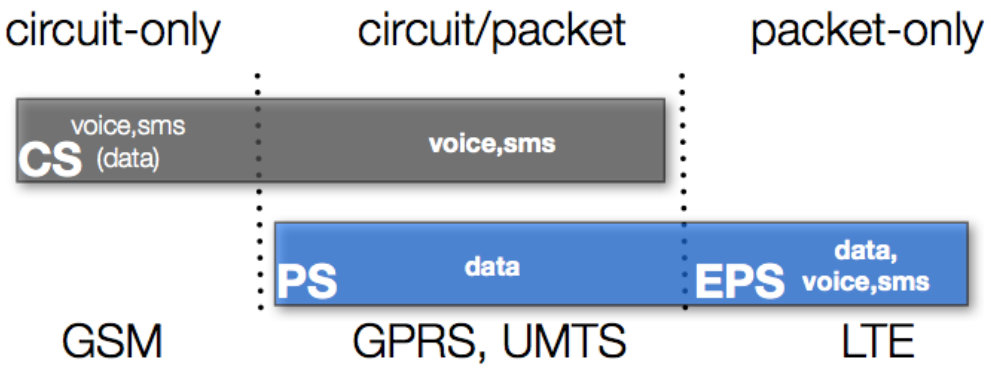
Coordinated network for seamless access and seamless mobility



Integrated, transparent **backhaul network** provides seamless access

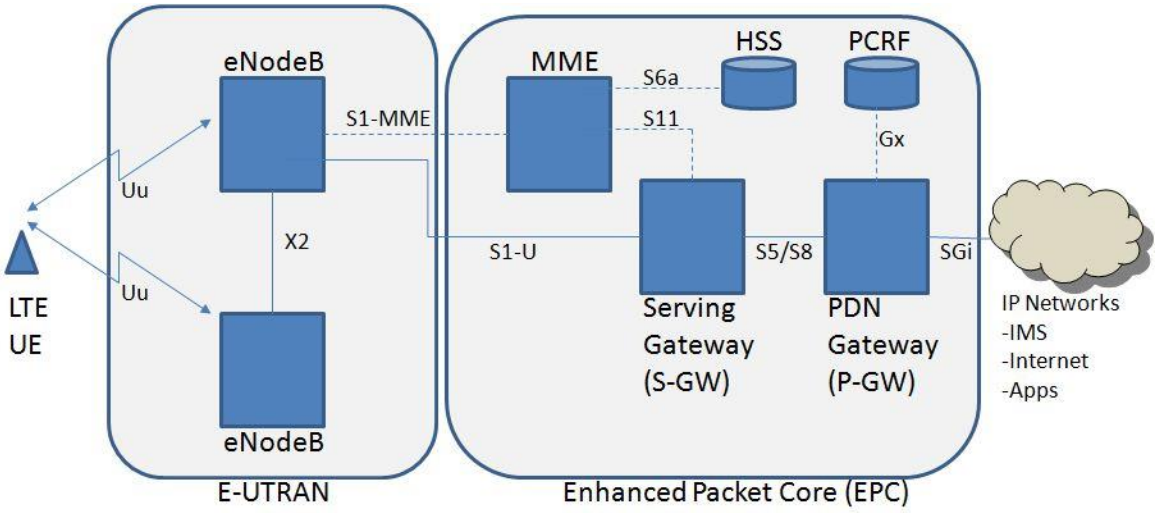
UMTS N/W 구조

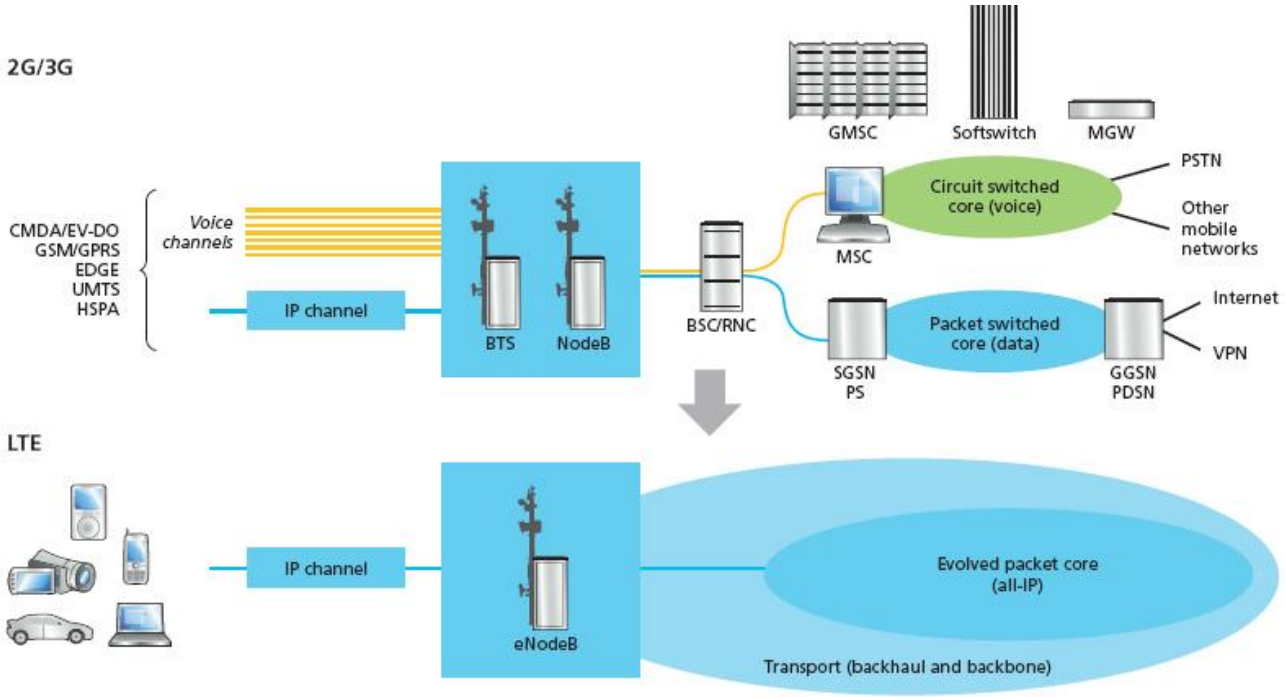




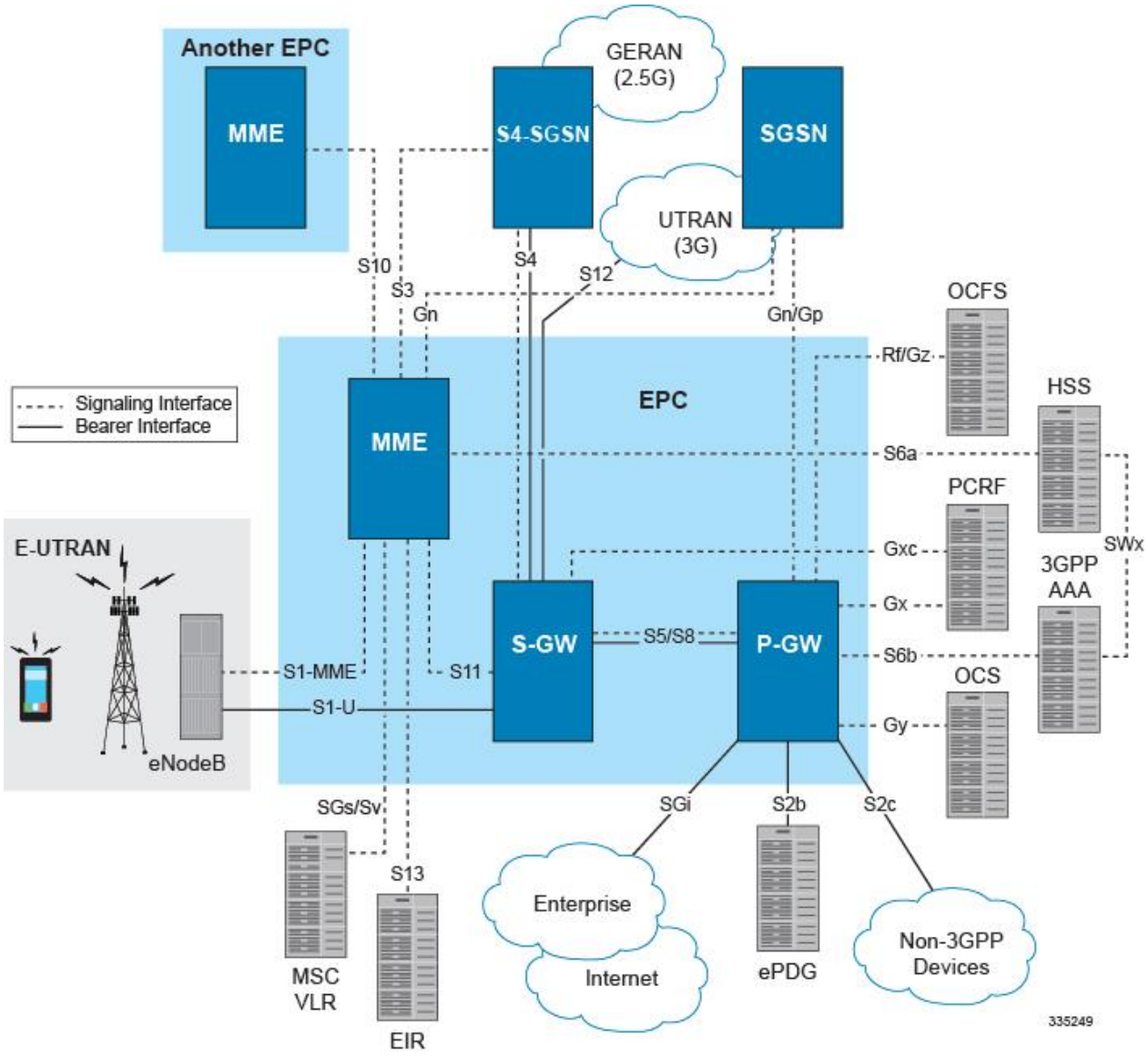
CS: Circuit-Switching, PS: Packet-Switching, EPS: Envolved-Packet-System

LTE N/W 구조(All IP)



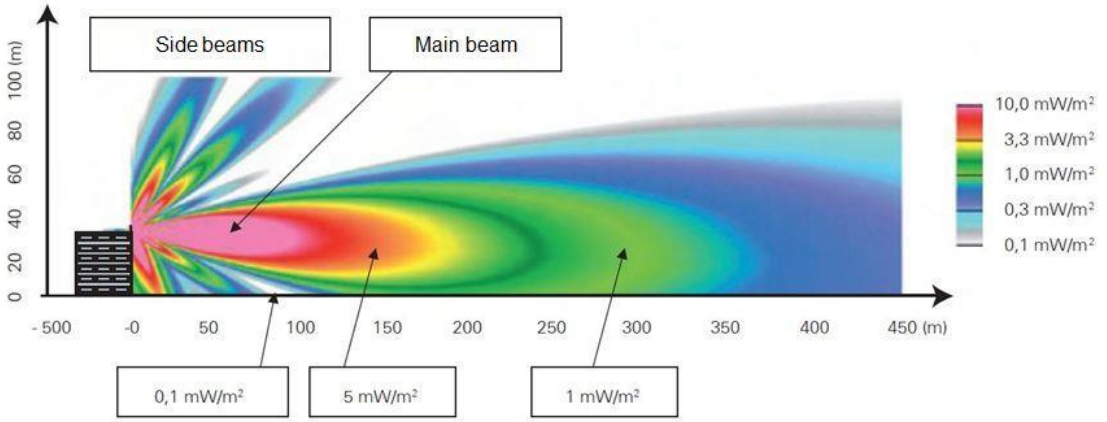


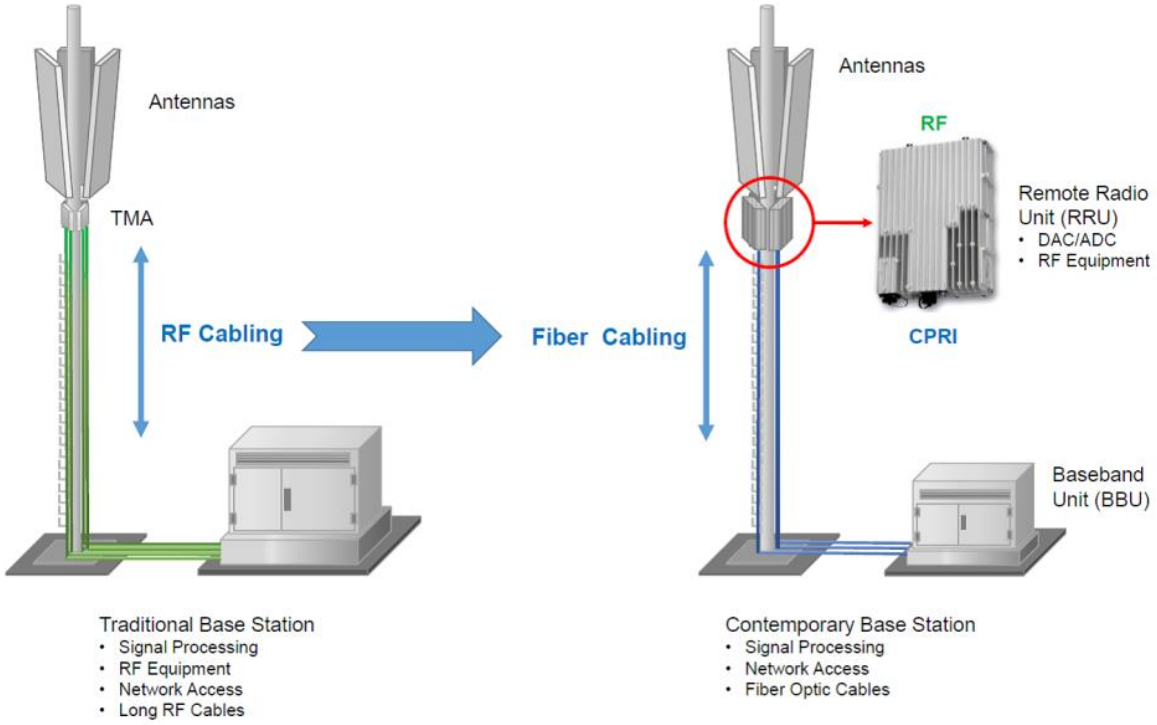
LTE EPC 구조



* EPC: Evolved Packet Core

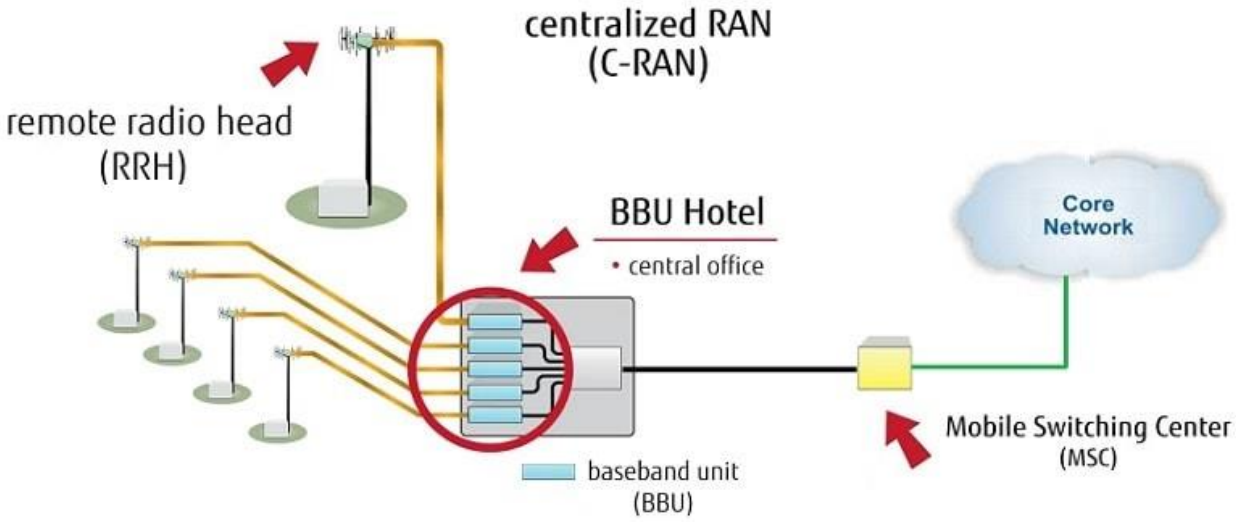
LTE eNB 구조

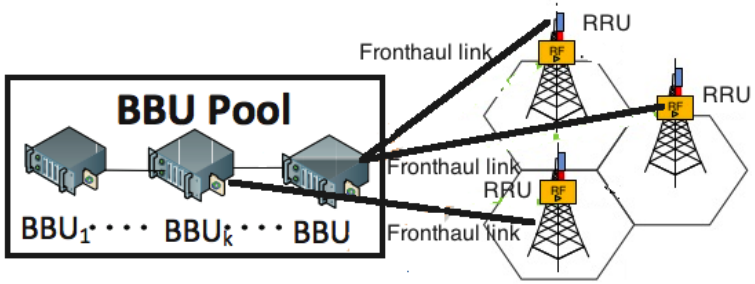


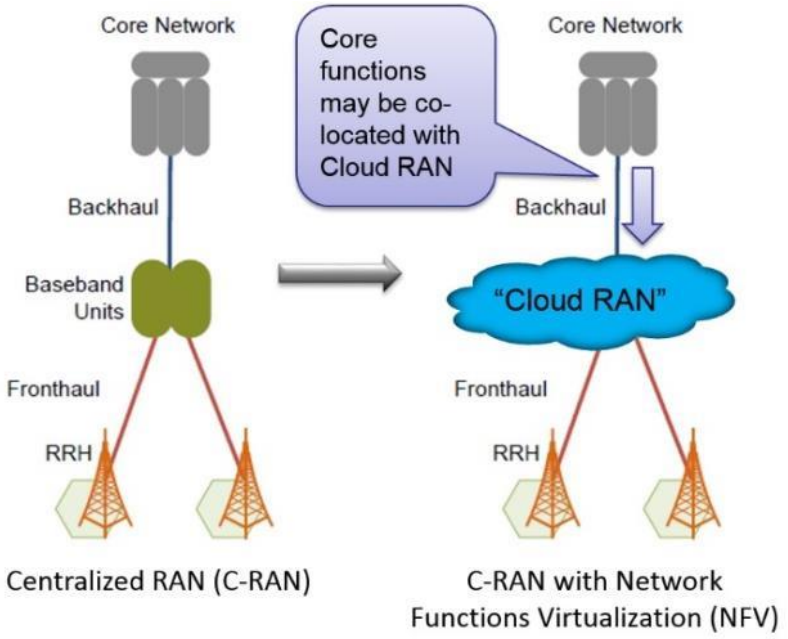


* eNB: evolved Node B
* CPRI: Common Public Radio Interface

기지국: BBU, RRH

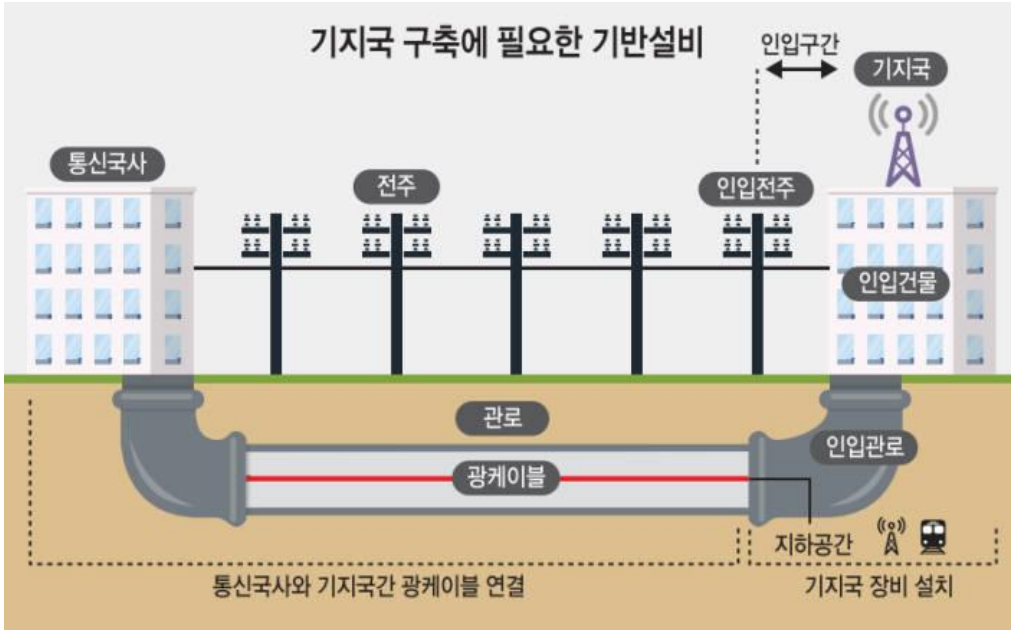






* BBU: Baseband Unit
* RRH: Remote Radio Head

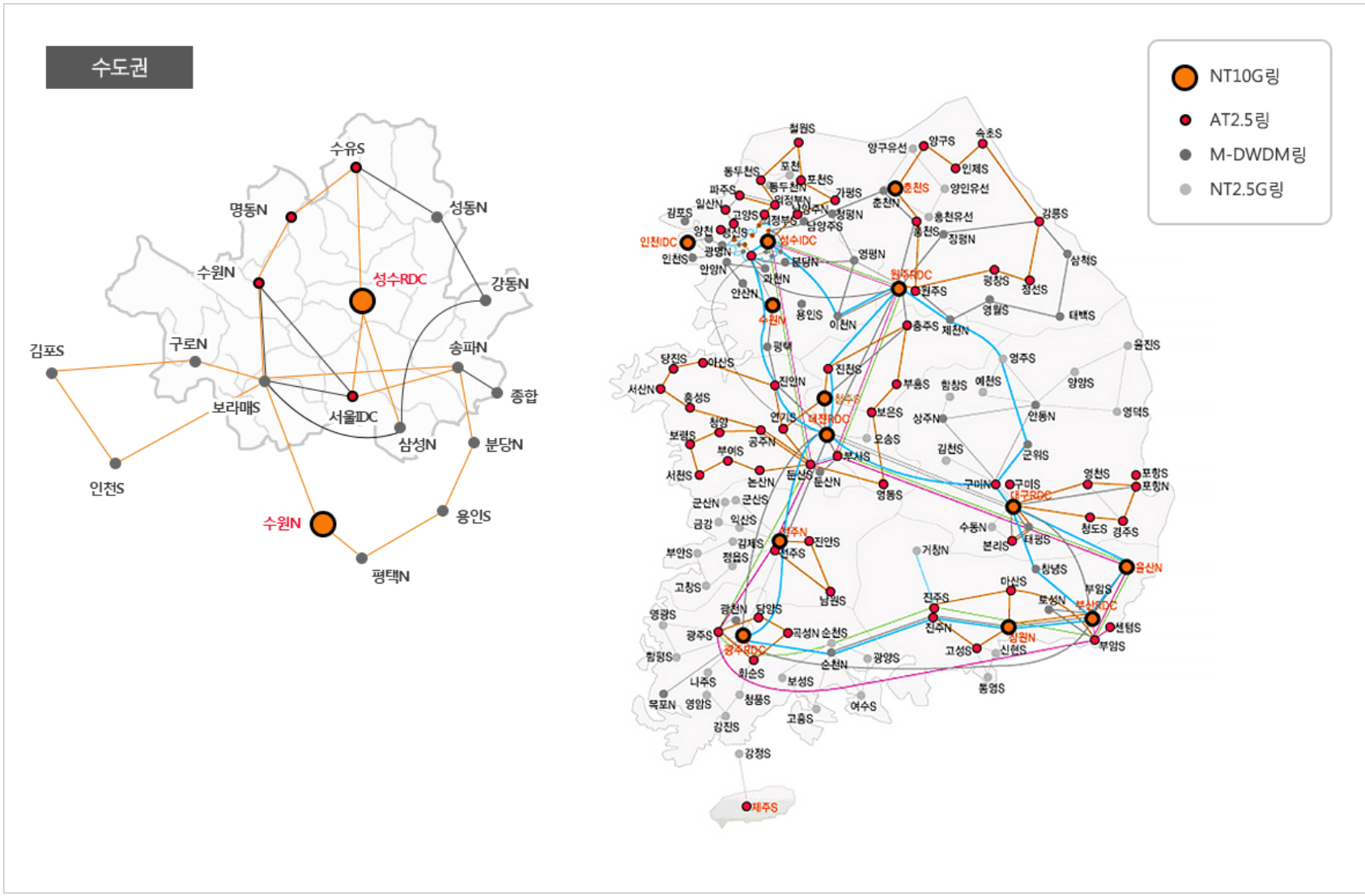
기지국 구축, 중계기(DAS)



Active DAS

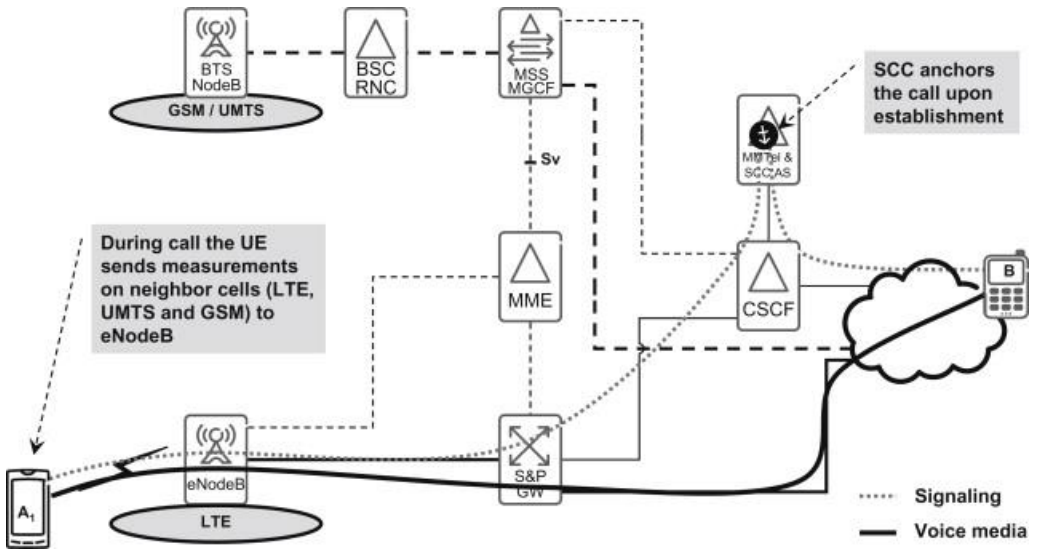
Passive DAS

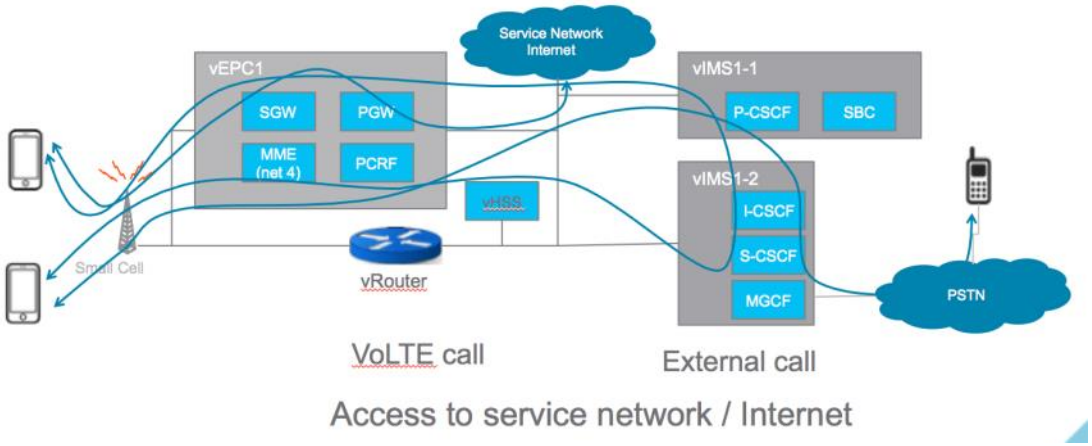
Backbone Network



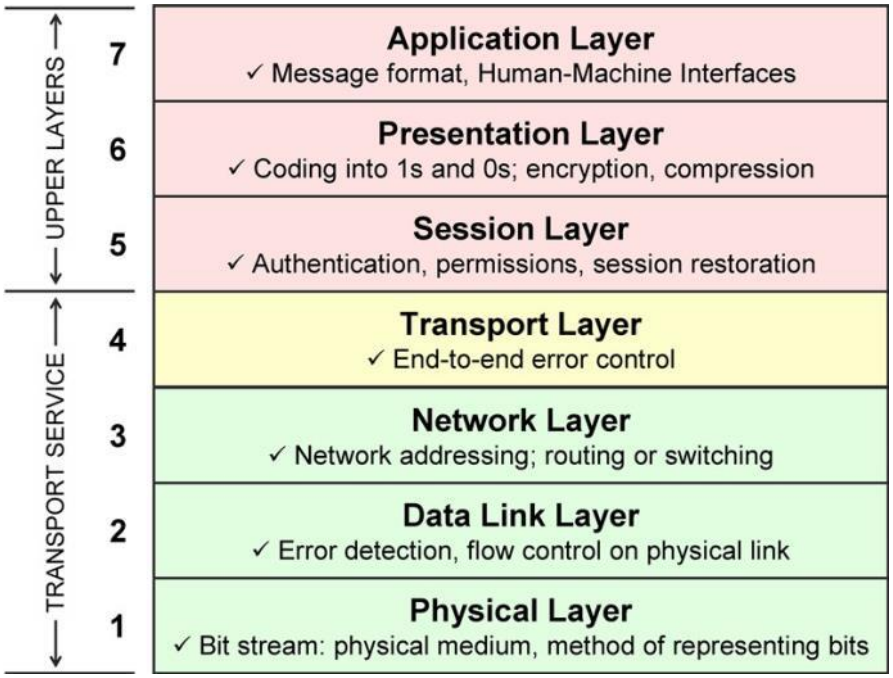
호처리

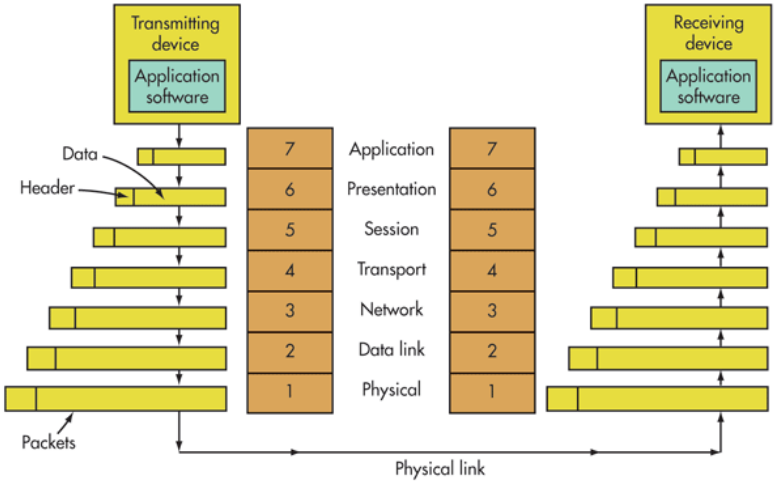
Call Processing Definition

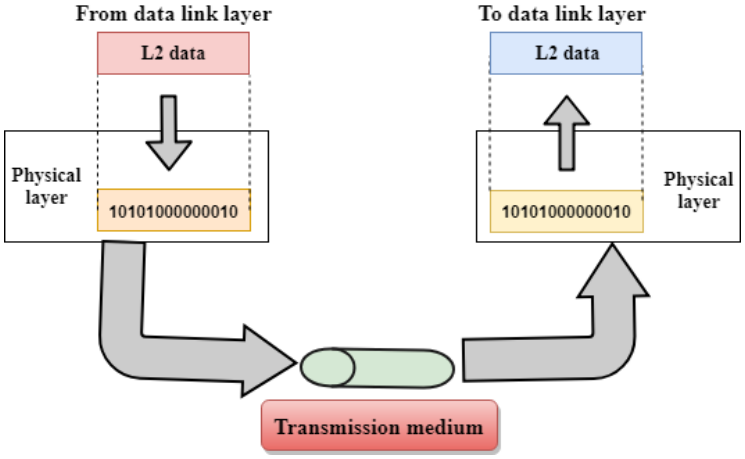




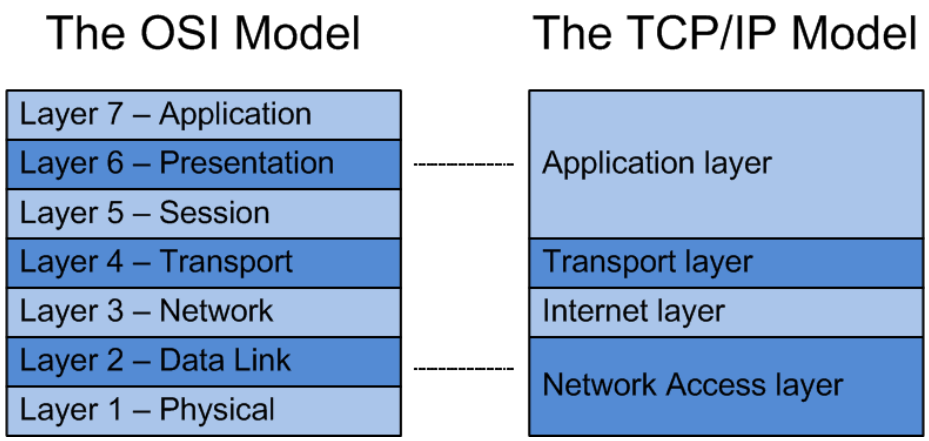
ISO, OSI 7 Layers

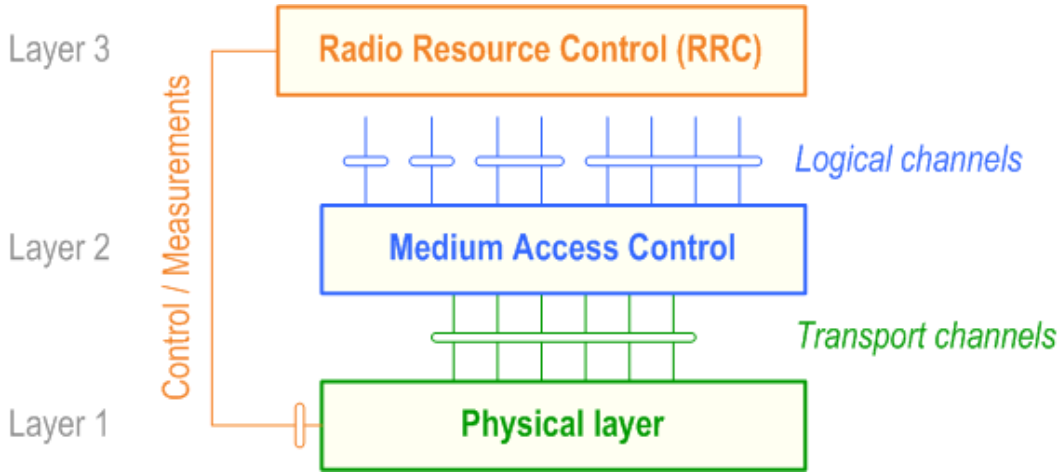






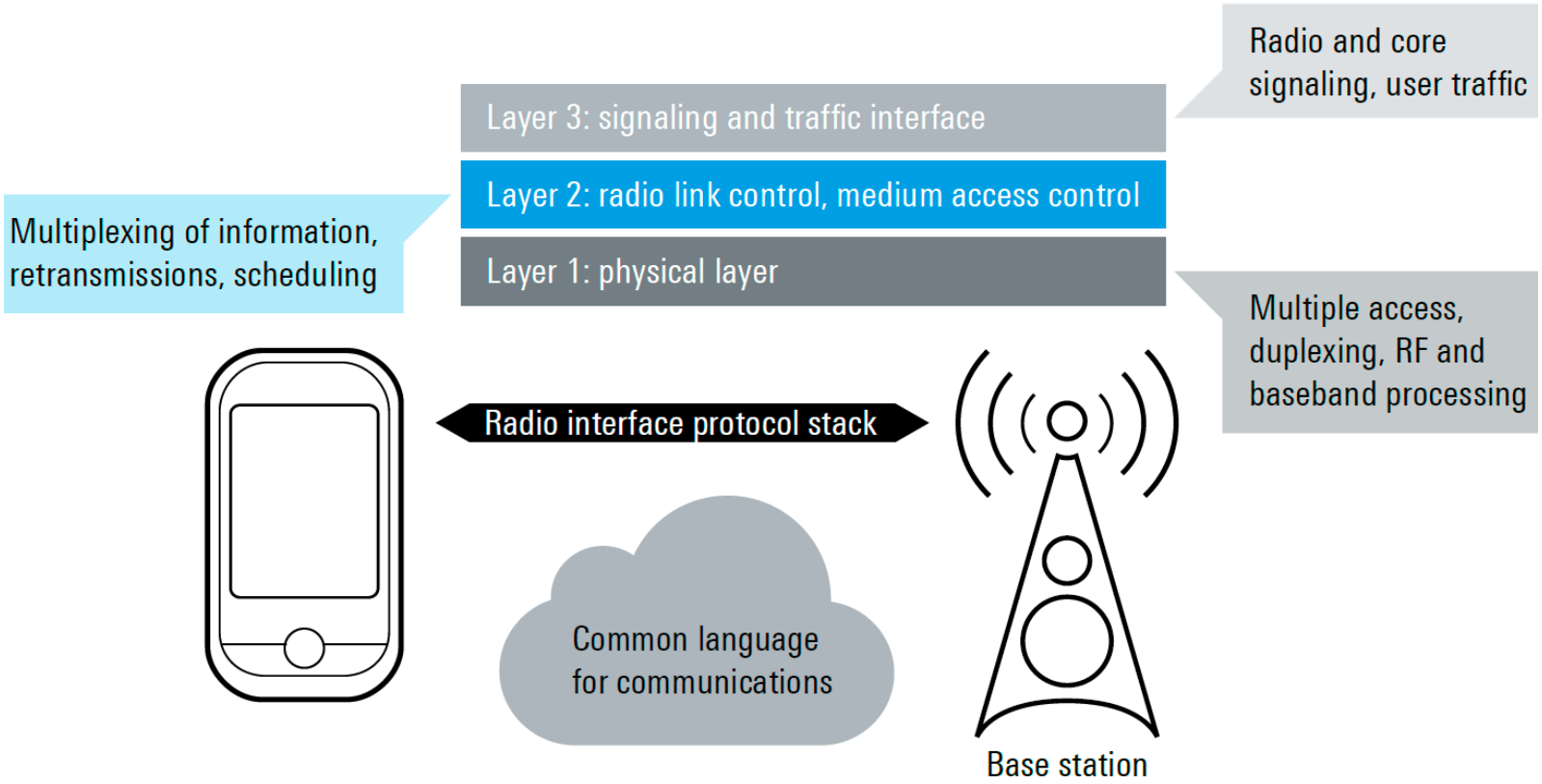
TCP/IP Model, 3GPP Radio Link Layering



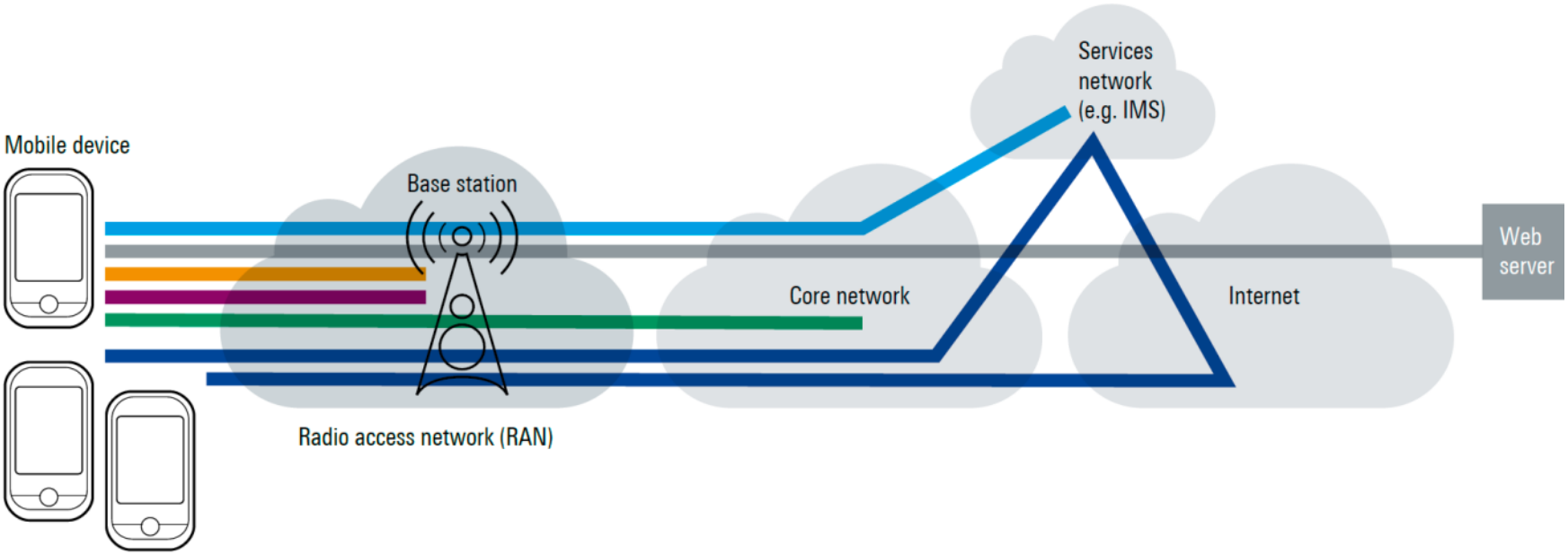


* OSI: 1983년
* TCP/IP: 1991년
* 3GPP: 1999년

3GPP Radio Link Layer Definition



End to End Signaling Examples

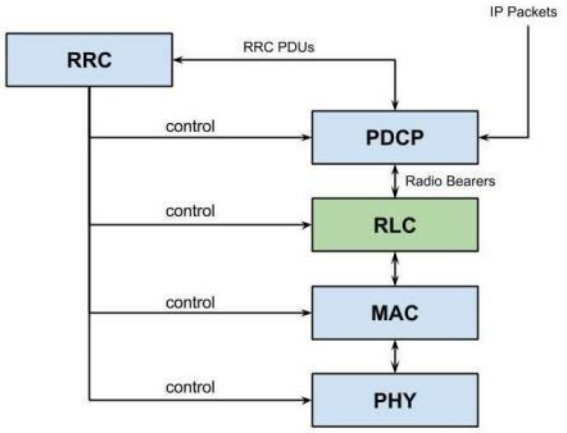


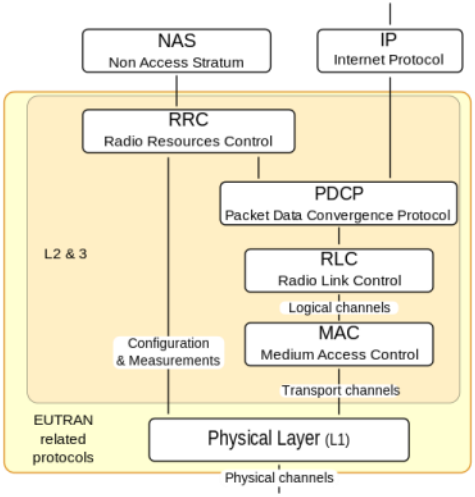
User traffic (e.g. video)
User traffic (e.g. voice and SMS)

Application-level signaling (e.g. IMS/SIP signaling)
Access stratum L3 signaling (e.g. handover signaling)

L1/L2 signaling (e.g. channel condition reporting)
Non-access stratum signaling (e.g. authentication signaling)

Control Data, User Data

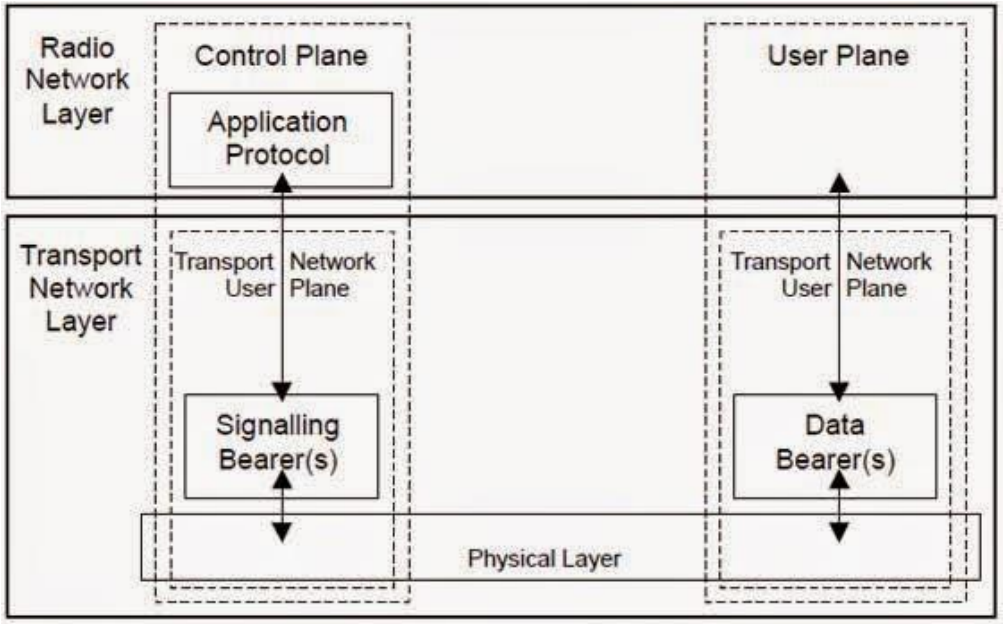


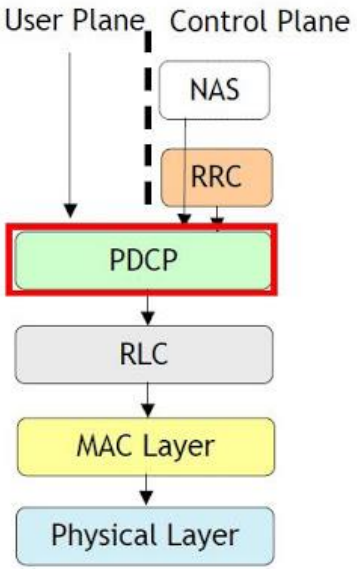


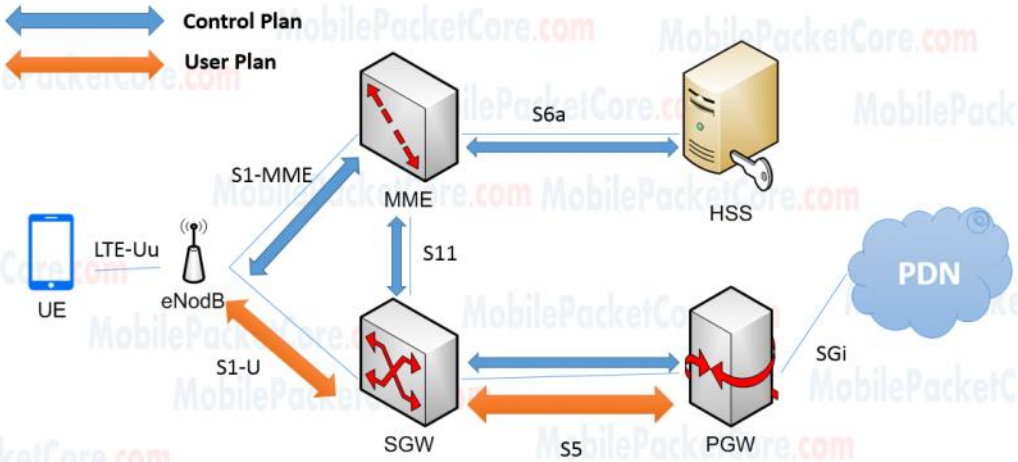
- Control Data: 제어신호, Signaling
- User Data: IP 데이터

- Control Data와 User Data는 서로 특성과 역할이 달라서 통신망에서 처리방법과 노드가 다름

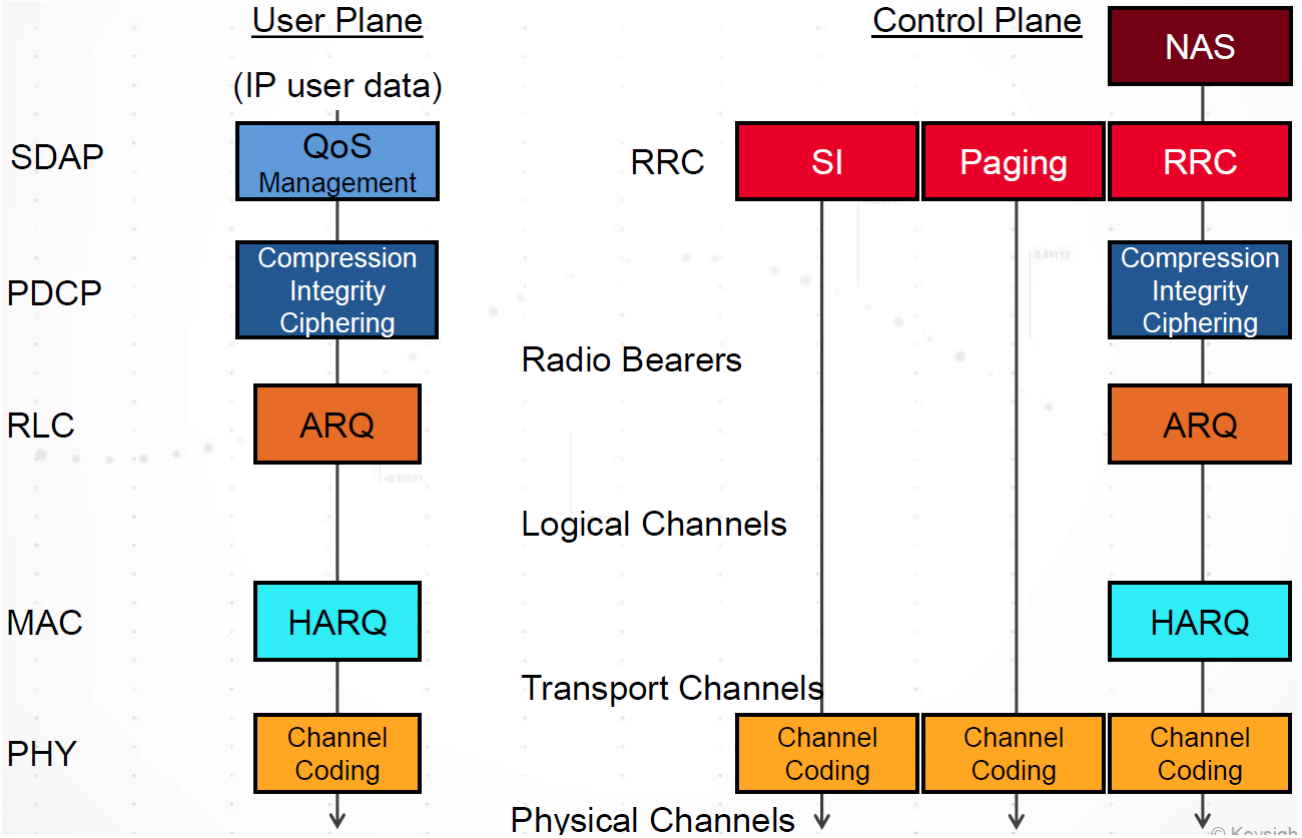
Control Plane, User Plane







Control Plane, User Plane 동작



단방향/양방향 통신

Control Data, User Data의 Logical 통신선로

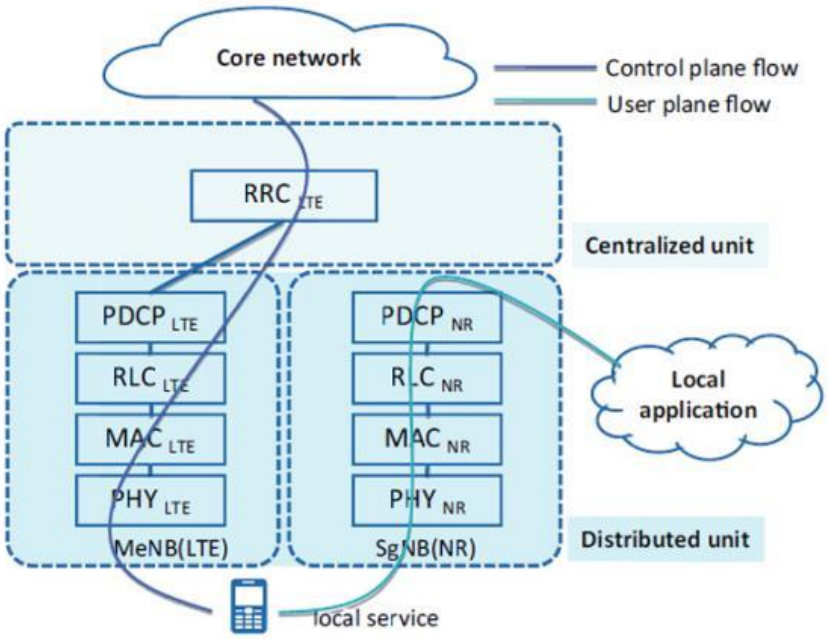
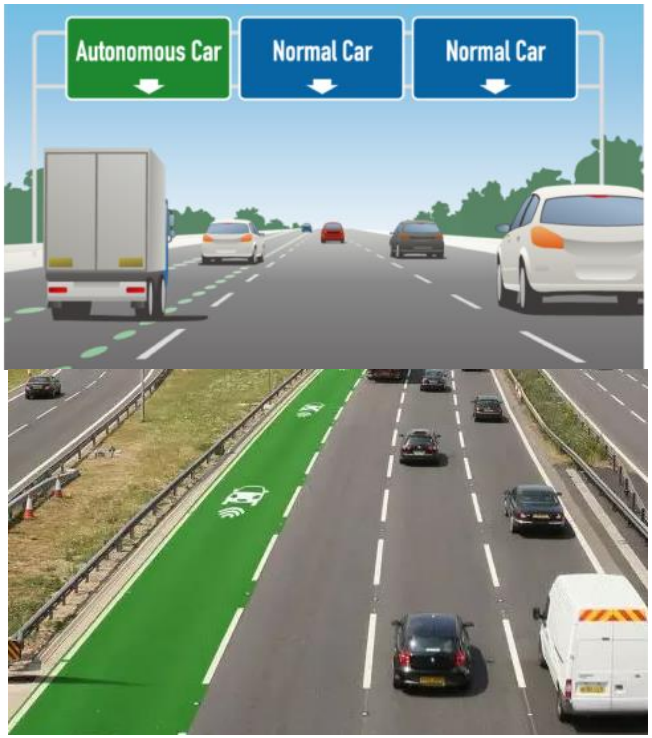
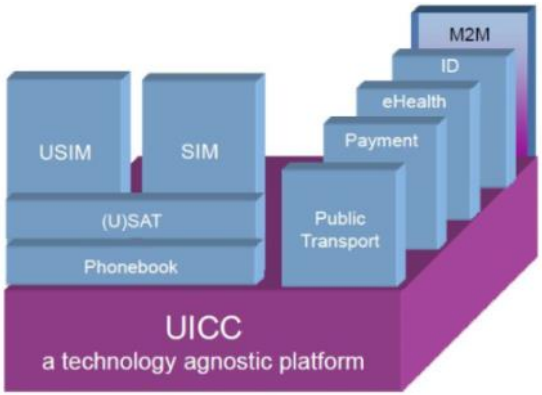


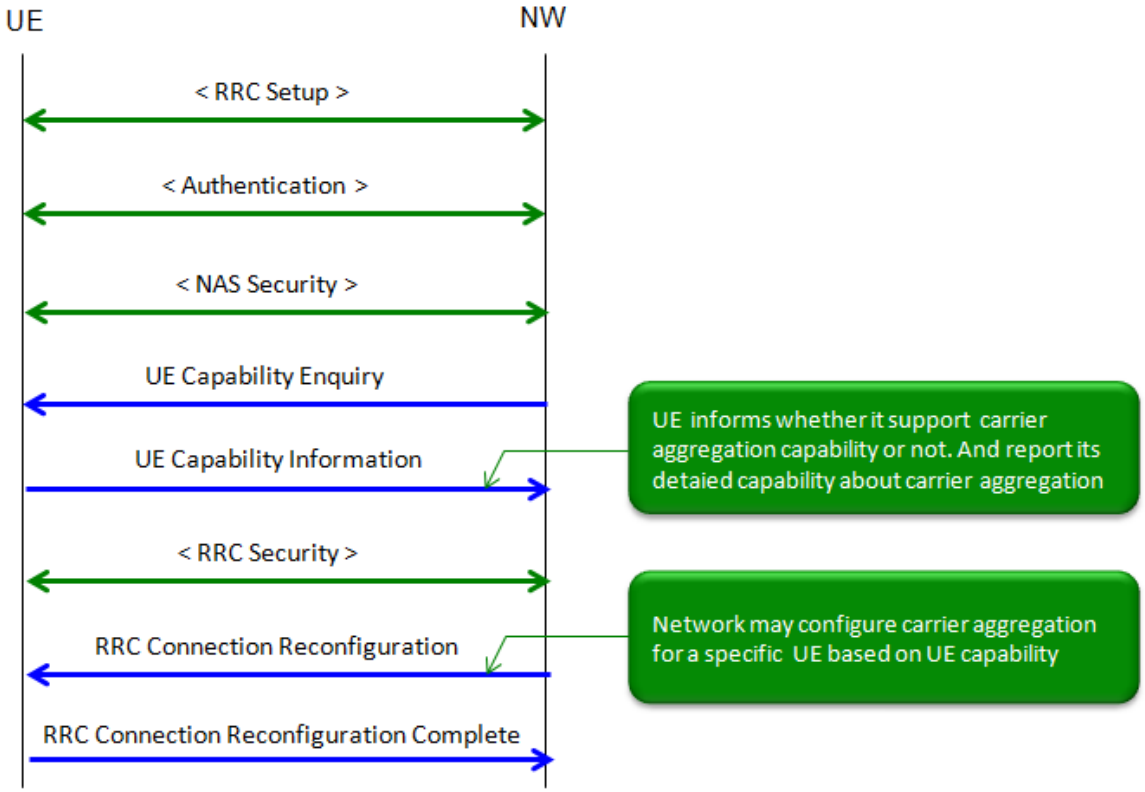
Figure 3. Protocol deployment in a local application scenario.



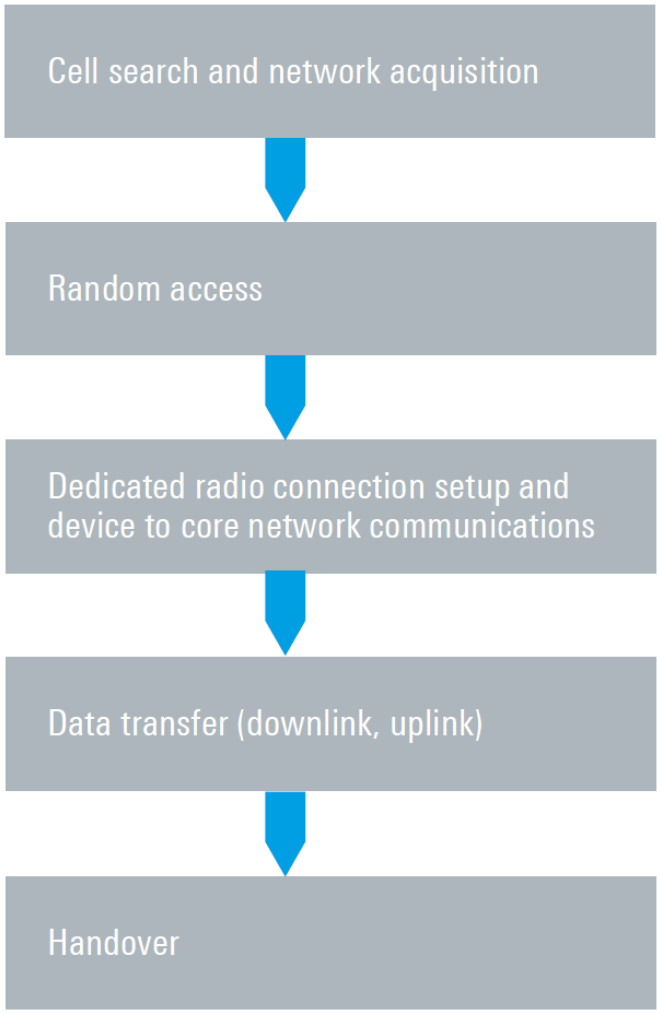
USIM, 보안처리


2.5cm
Mini SIM
(25 x 15 x 0.76mm)
Micro SIM
(15 x 12 x 0.76mm)
Nano SIM
(12.3 x 8.8 x 0.67mm)
eSIM (MFF2)
(6 x 5 x 0.9mm)


M2M
ID
eHealth
Payment
Public Transport
USIM
SIM
(U)SAT
Phonebook
UICC
a technology agnostic platform


UE
NW
< RRC Setup >
< Authentication >
< NAS Security >
UE Capability Enquiry
UE Capability Information
UE informs whether it support carrier aggregation capability or not. And report its detaied capability about carrier aggregation
< RRC Security >
RRC Connection Reconfiguration
Network may configure carrier aggregation for a specific UE based on UE capability
RRC Connection Reconfiguration Complete

Overall Call Processing



- Downlink synchronization
- Suitable cell selection

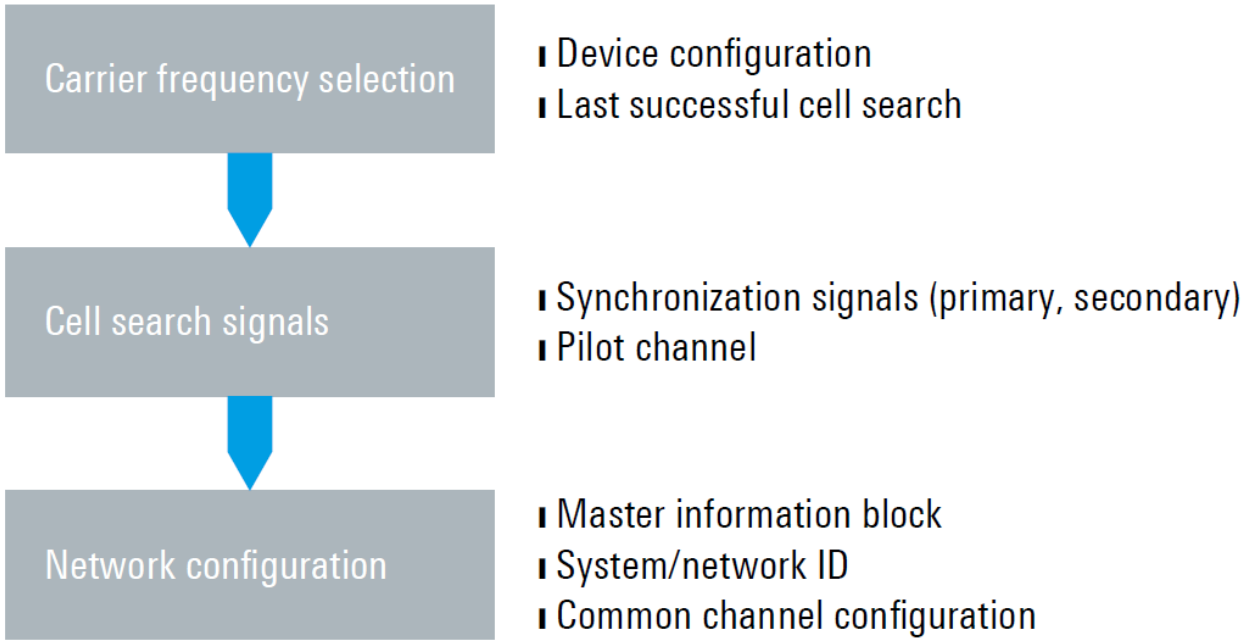
- Uplink synchronization
- Device to radio access network communications

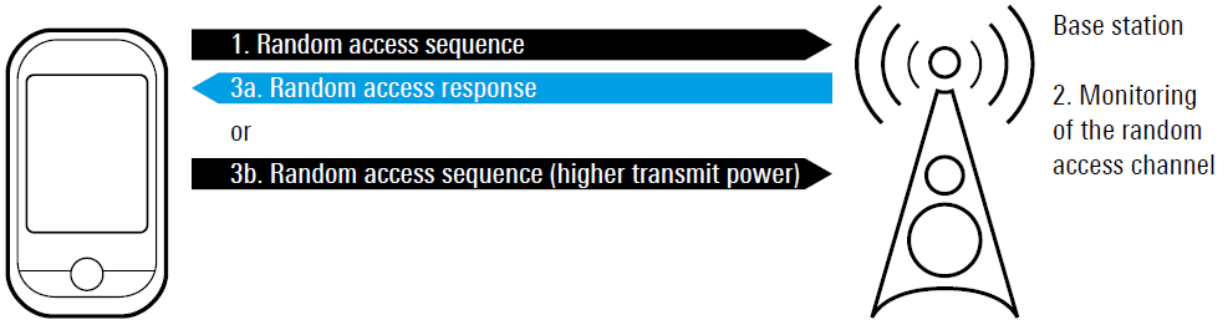
- Authentication
- Security
- IP address allocation

- Base station scheduler

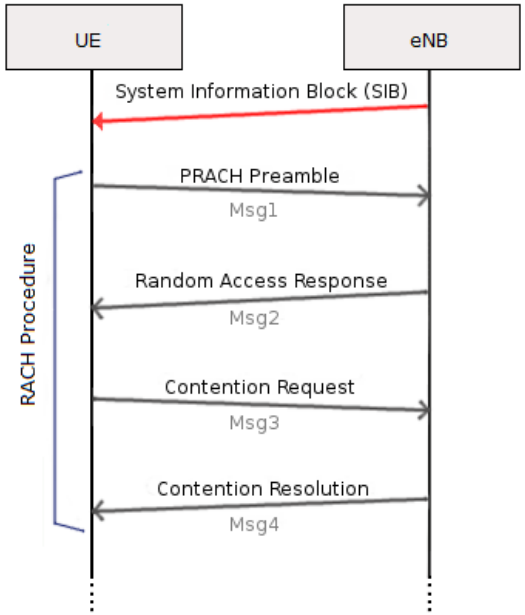
- Device measurements
- Base station decisions

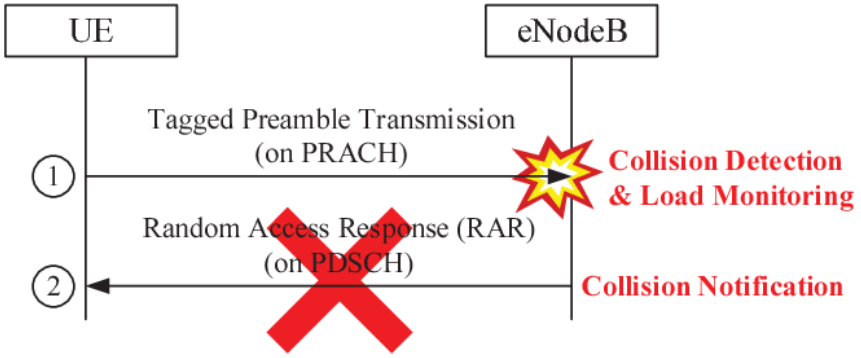
Cell Search, Random Access

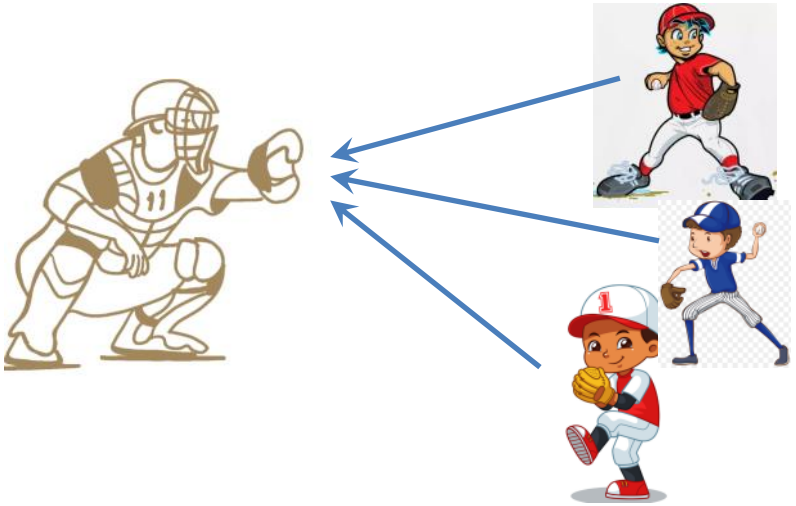




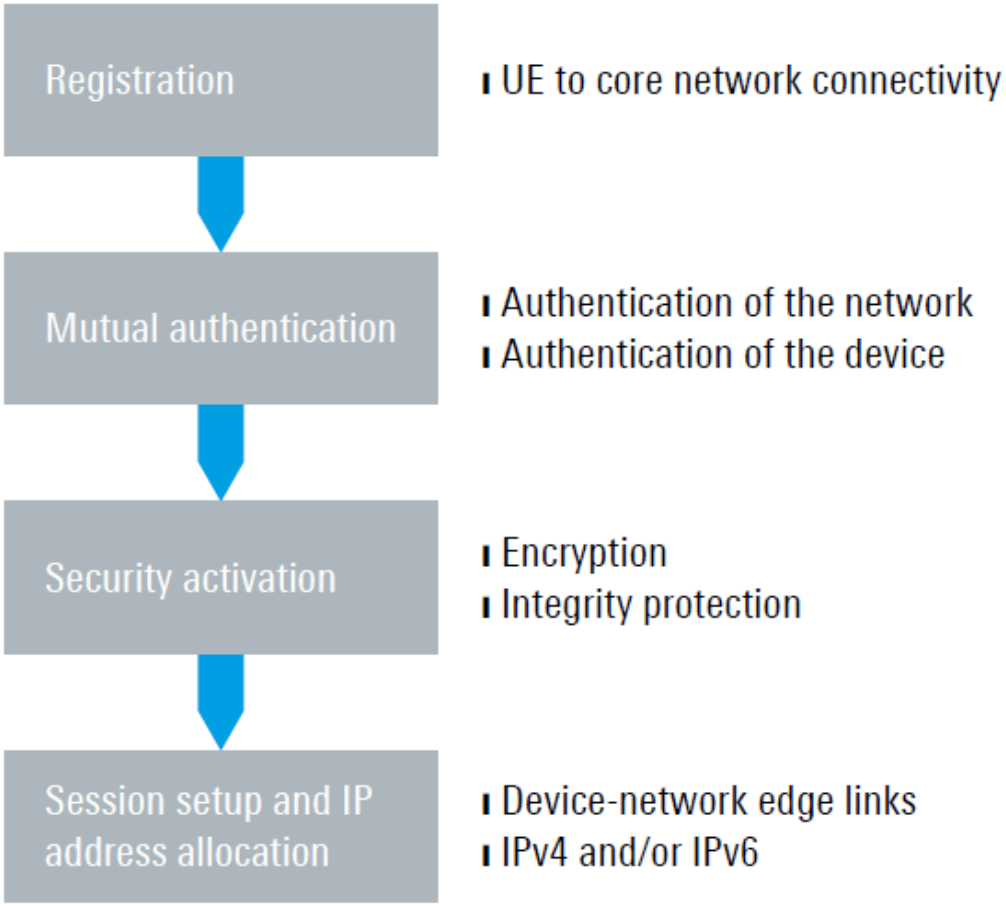
Random Access에서 Collision 발생







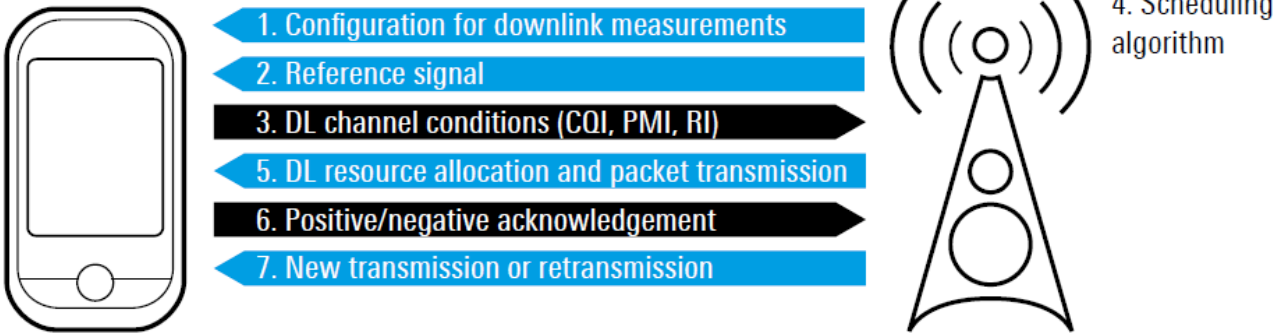
NAS Message Processing



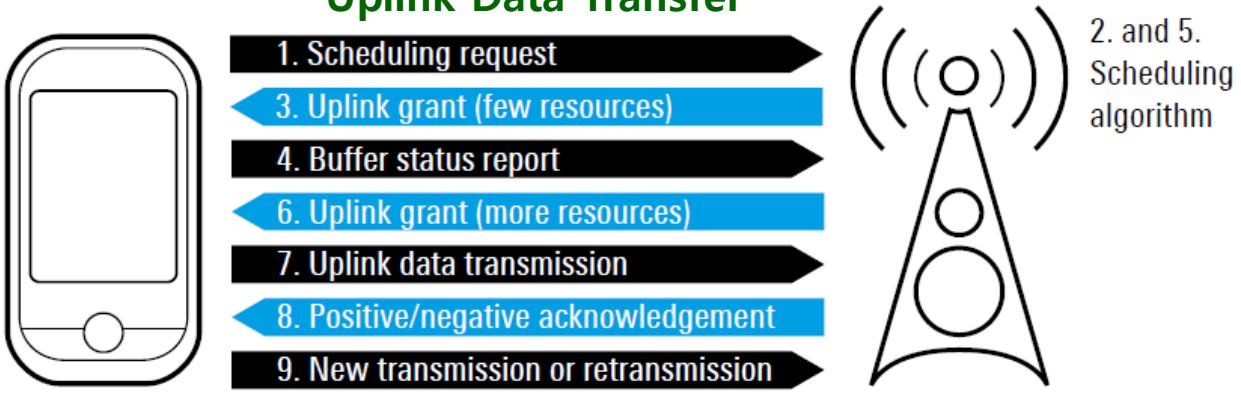
* NAS: Non-Access Stratum

Packet Data Transfer

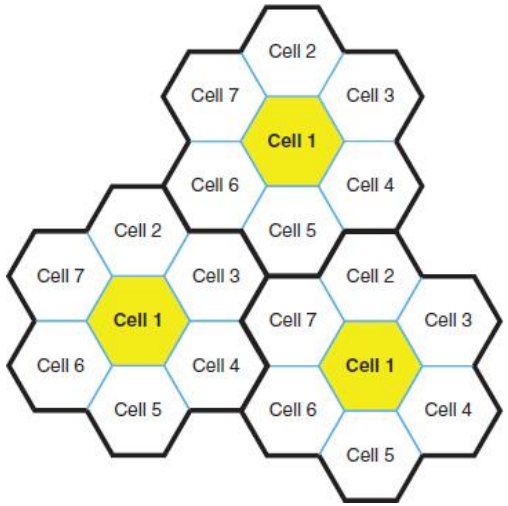
Downlink Data Transfer

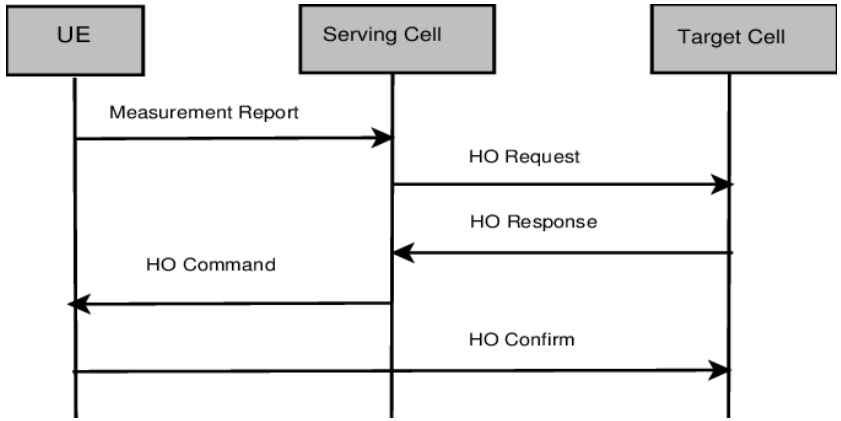


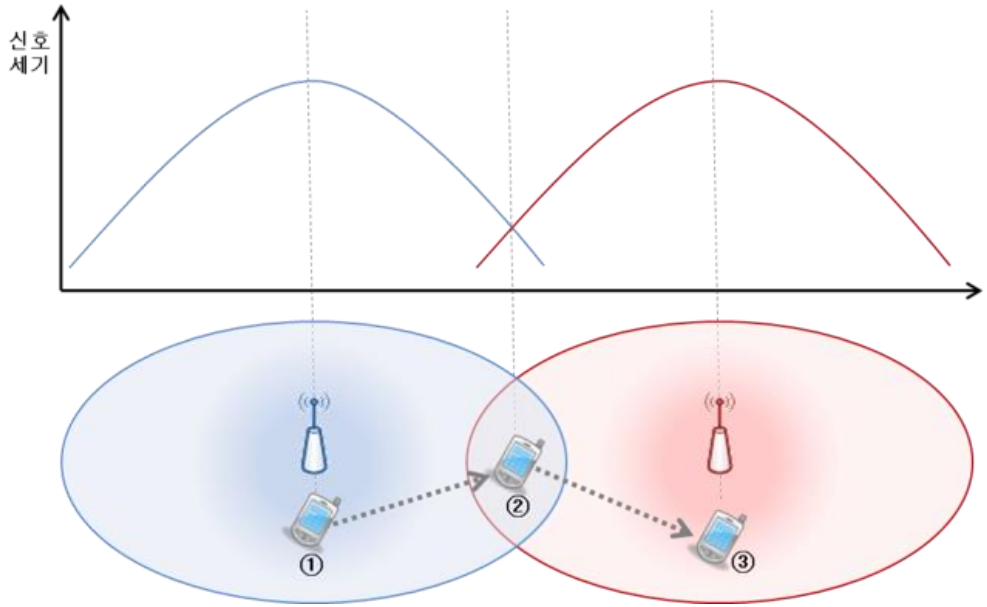
Uplink Data Transfer



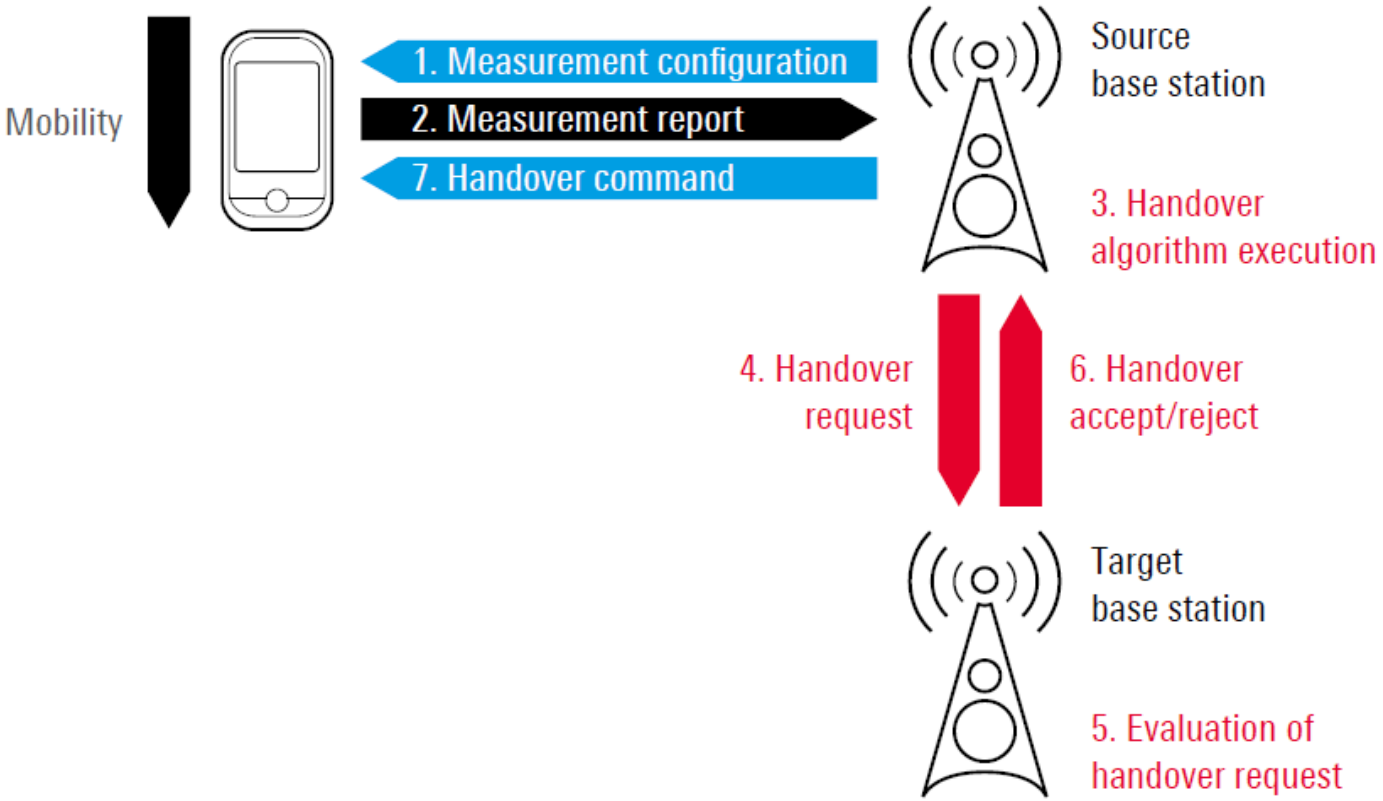
Handover


Cell 2
Cell 7
Cell 3
Cell 1
Cell 6
Cell 4
Cell 5
Cell 2
Cell 7
Cell 3
Cell 1
Cell 6
Cell 4
Cell 5
Cell 2
Cell 7
Cell 3
Cell 1
Cell 6
Cell 4
Cell 5

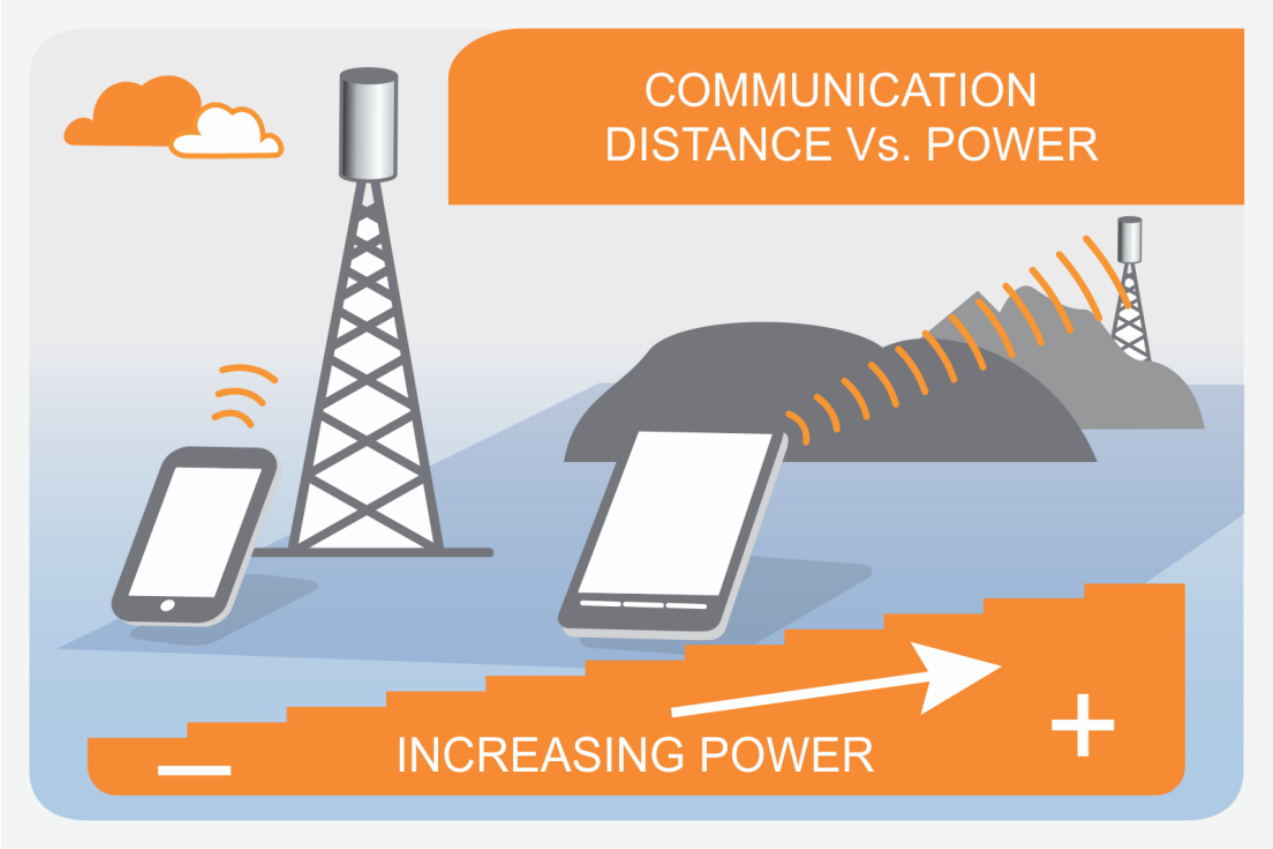

UE
Serving Cell
Target Cell
Measurement Report
HO Request
HO Response
HO Command
HO Confirm


신호
세기
①
②
③

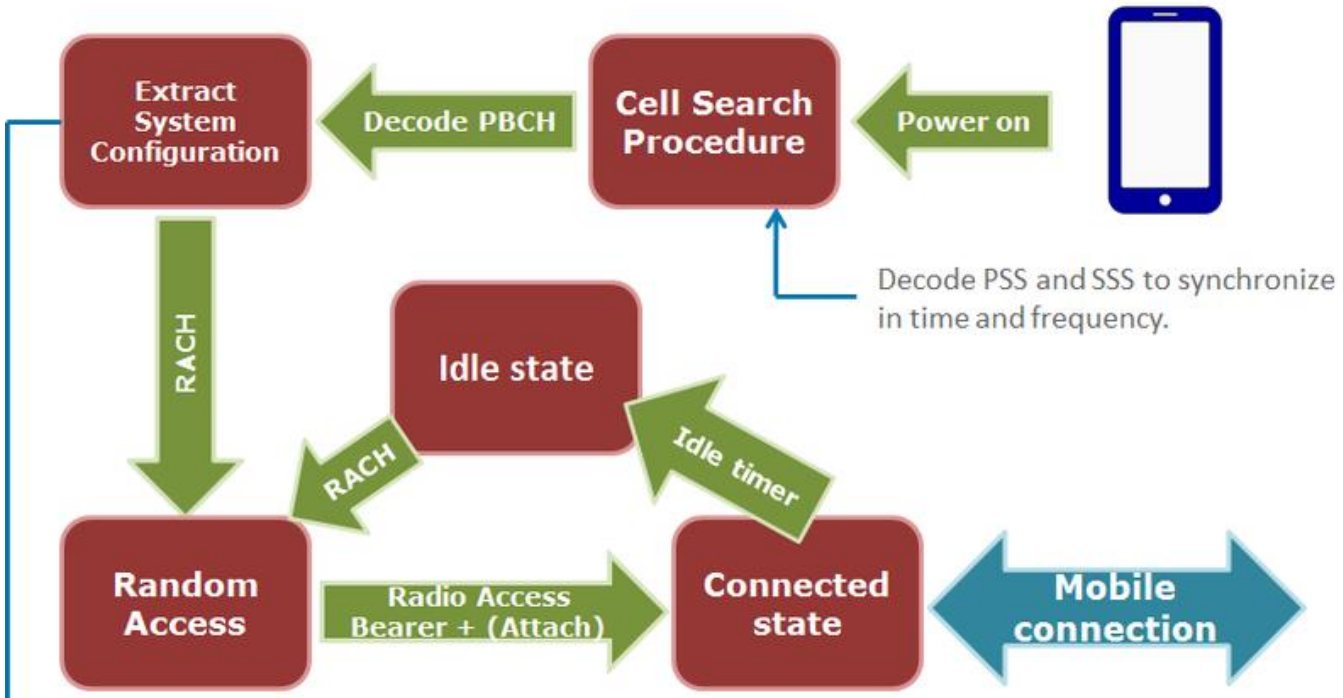
Handover Steps



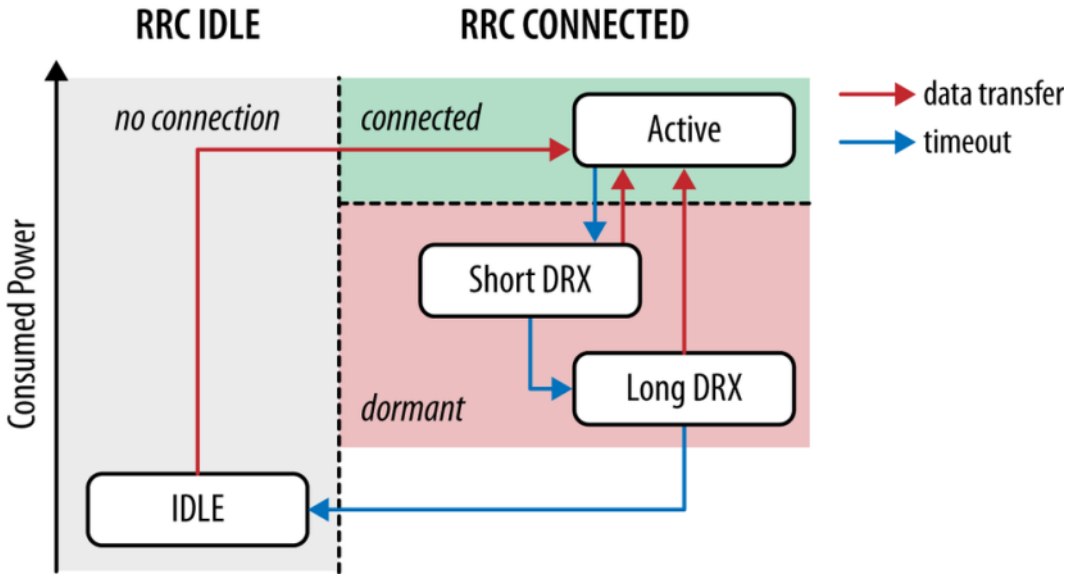
Power Control

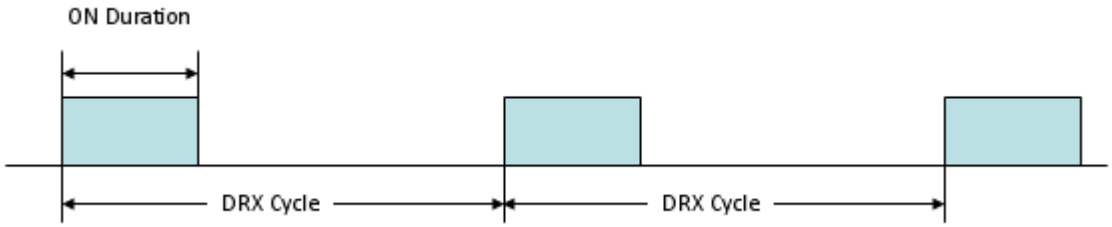


단말기 동작 순서


Extract System Configuration
Decode PBCH
Cell Search Procedure
Power on
Decode PSS and SSS to synchronize in time and frequency.
RACH
Idle state
RACH
Idle timer
Random Access
Radio Access Bearer + (Attach)
Connected state
Mobile connection
• System configuration
– Decode Master Information Block (MIB) from PBCH
– Decode System Information Blocks (SIBs) from PDSCH

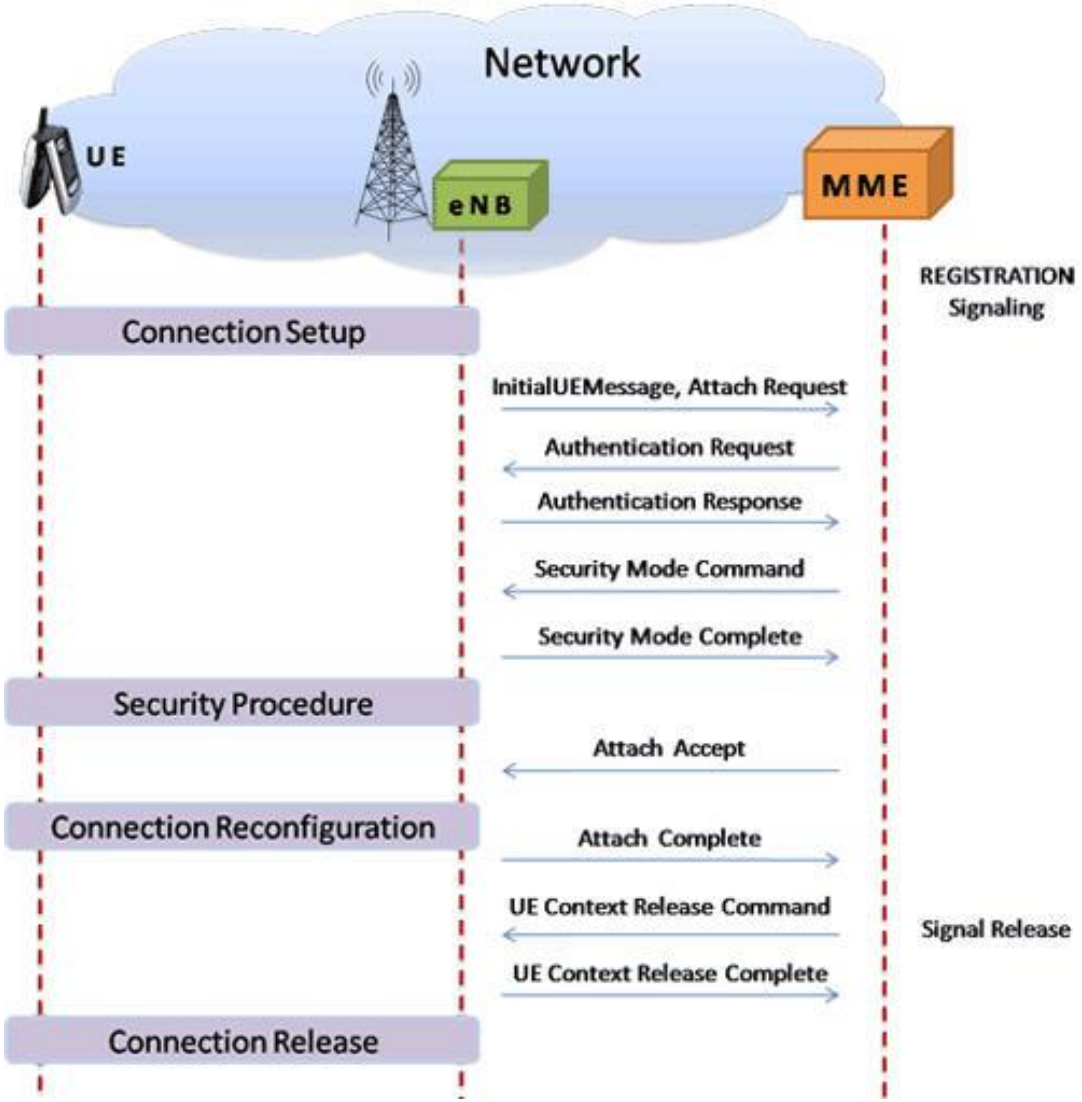
UE State Diagram, DRX Cycle



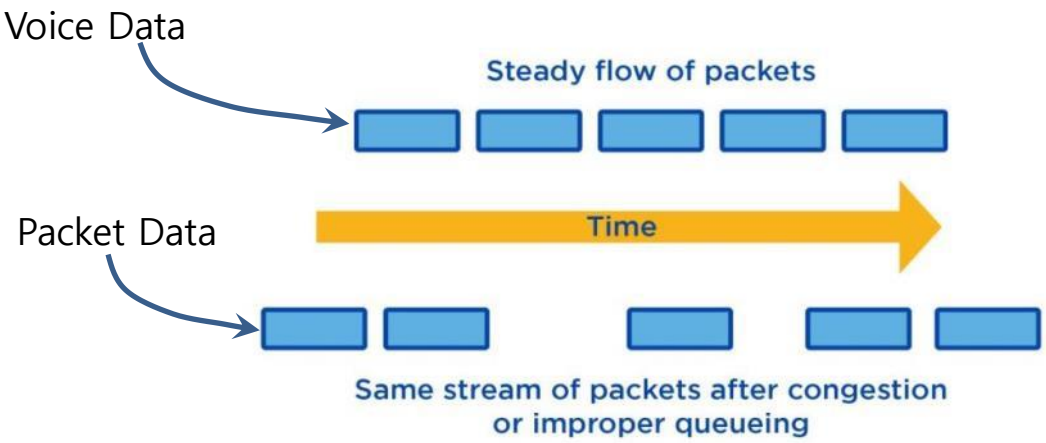


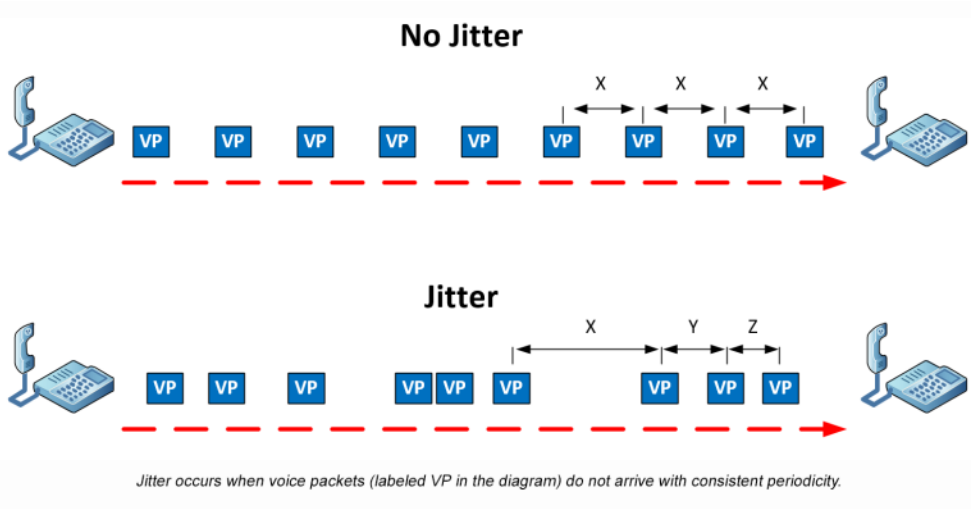
* UE: User Equipment
* DRX: Discontinuous Reception

LTE 호처리 예

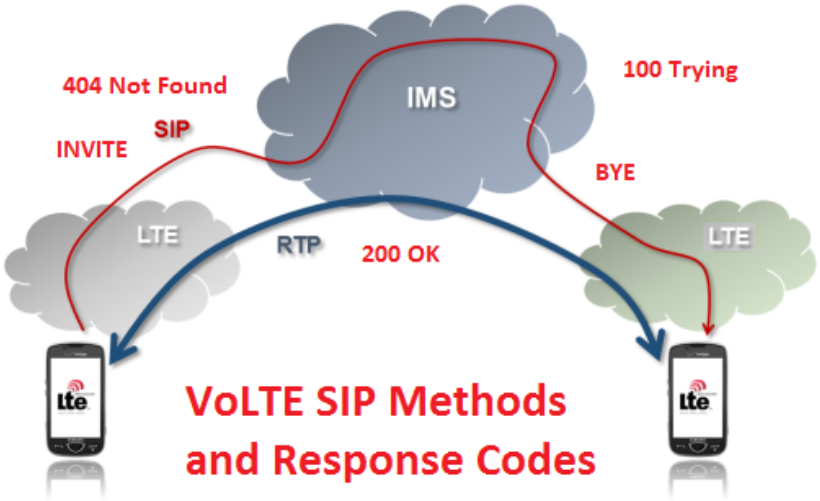

Network
UE
eNB
MME
REGISTRATION
Signaling
Connection Setup
InitialUEMessage, Attach Request
Authentication Request
Authentication Response
Security Mode Command
Security Mode Complete
Security Procedure
Attach Accept
Connection Reconfiguration
Attach Complete
UE Context Release Command
UE Context Release Complete
Signal Release
Connection Release

Voice Data, Packet(Datagram) Data 특징

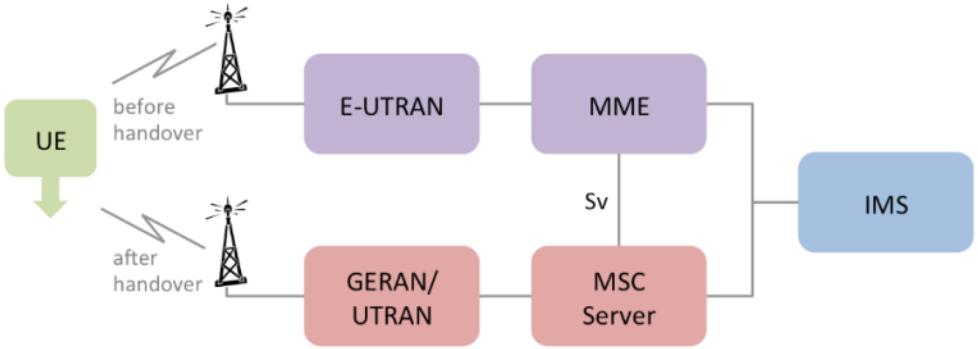




VoLTE, SRVCC



Simplified VoLTE SRVCC Architecture

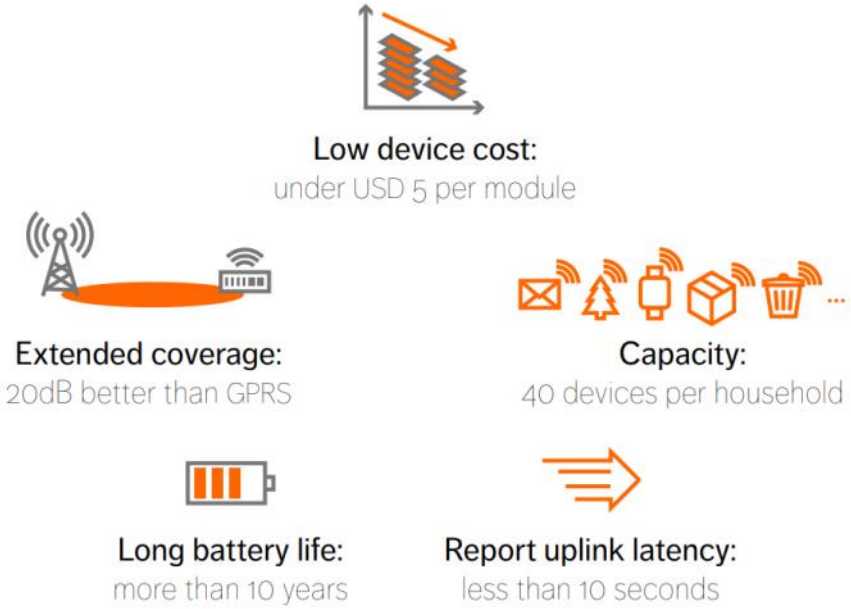


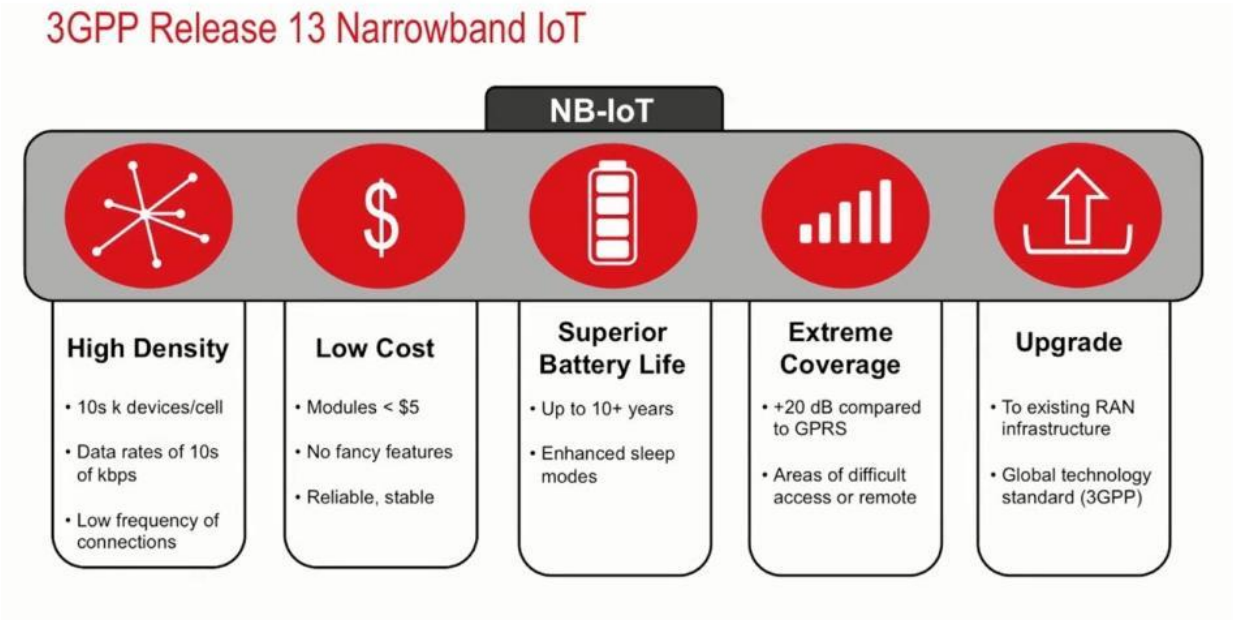
IMS – IP Multimedia Subsystem
MME – Mobility Management Entity
MSC Server – Mobile Switching Centre Server
E-UTRAN – Evolved Universal Terrestrial Radio Access Network
GERAN – GSM/EDGE Radio Access Network
UTRAN – Universal Terrestrial Radio Access Network
UE – User Equipment

* SRVCC: Single Radio-Voice Call Continuity

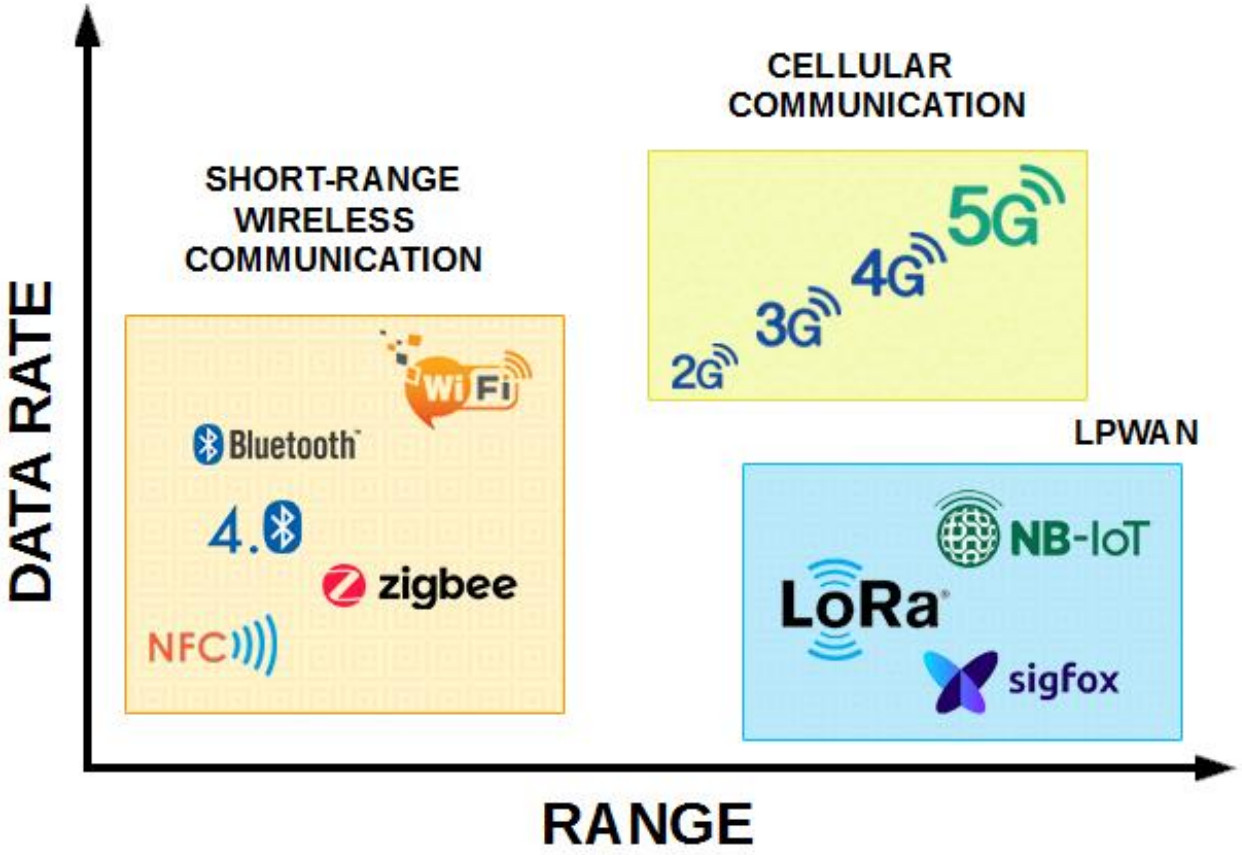
IoT 서비스 대응

IoT 서비스 특징(철학?)

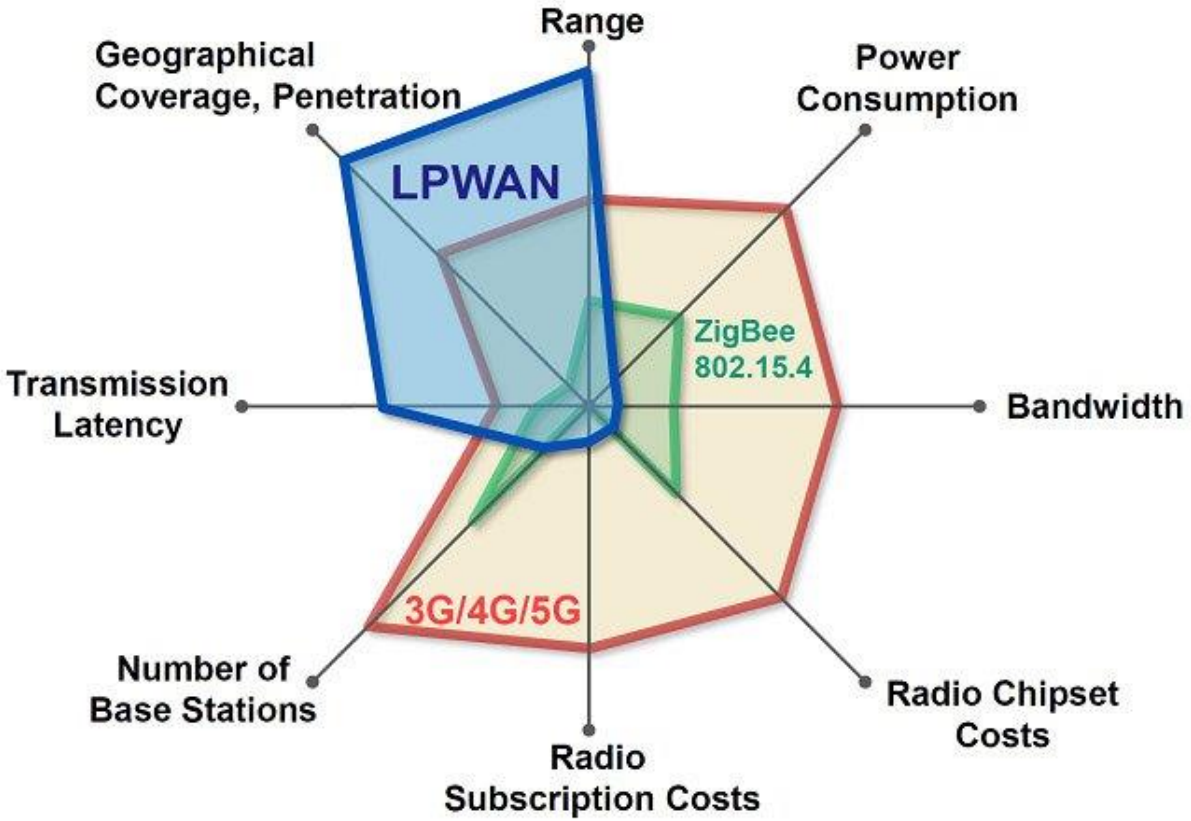

Low device cost:
under USD 5 per module
Extended coverage:
20dB better than GPRS
Capacity:
40 devices per household
Long battery life:
more than 10 years
Report uplink latency:
less than 10 seconds


3GPP Release 13 Narrowband IoT
NB-IoT
High Density
• 10s k devices/cell
• Data rates of 10s of kbps
• Low frequency of connections
Low Cost
• Modules < $5
• No fancy features
• Reliable, stable
Superior Battery Life
• Up to 10+ years
• Enhanced sleep modes
Extreme Coverage
• +20 dB compared to GPRS
• Areas of difficult access or remote
Upgrade
• To existing RAN infrastructure
• Global technology standard (3GPP)

IoT용 무선통신 비교(1)



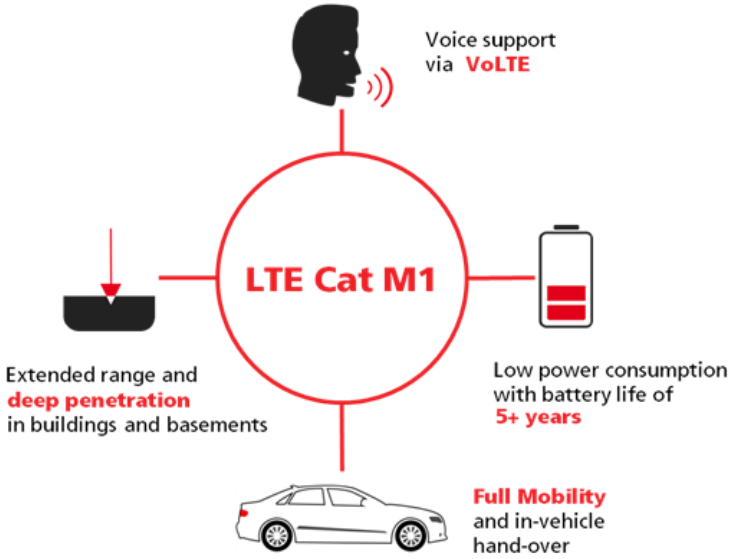
IoT용 무선통신 비교(2)

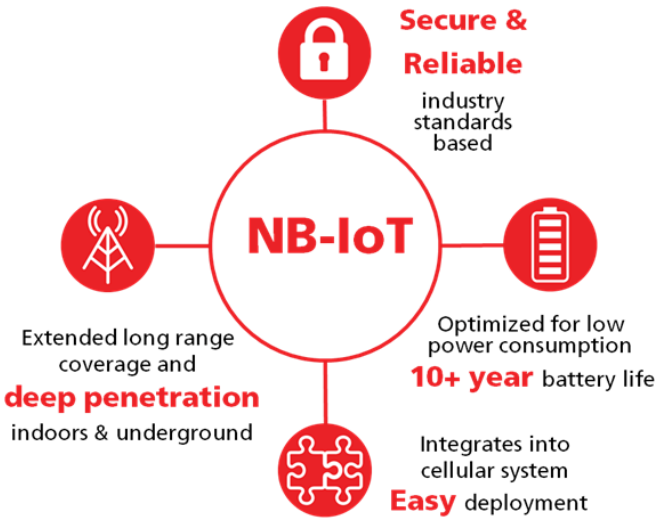


* LPWAN: Low Power Wide Area Network

LTE-Cat M1, NB-IoT

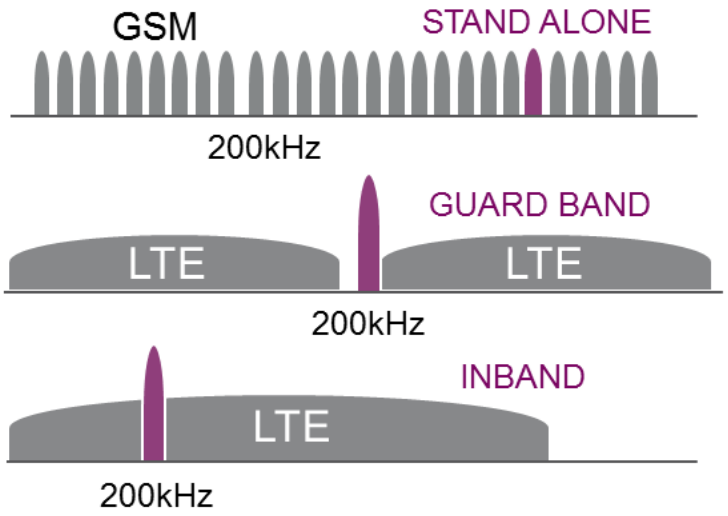
	LTE-M	NB-IoT
Also known as	eMTC, LTE Cat-M1	LTE Cat-NB1
Specification	Based on LTE	Based on a subset of LTE
Bandwidth	1.08 MHz (equivalent to an LTE channel)	180 kHz (fits into a GSM channel)
Max throughput	360 kbps	30/60 kbps
Network deployment	Relatively easy for operators to add to existing LTE networks	Easier for operators with GSM networks to incorporate
Frequency deployment	LTE in-band	LTE in-band, LTE guard band and GSM repurposing
Voice/data support	Voice and data	Data only
Range	Up to 4x	Up to 7x
Mobility/cell reselection	Yes	Limited
Module size	Suitable for wearables	
Power consumption	Up to 10 years of battery lifetime	

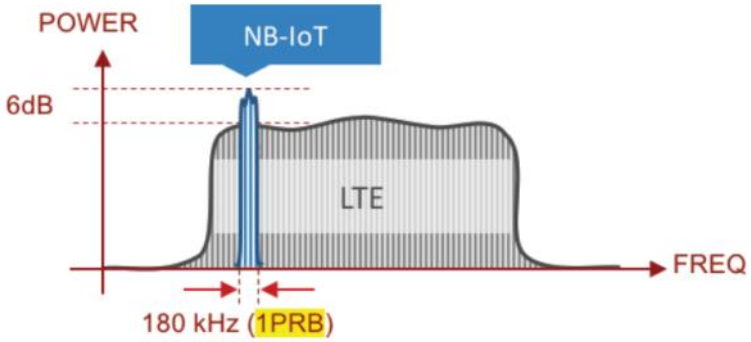




NB-IoT 구현방법

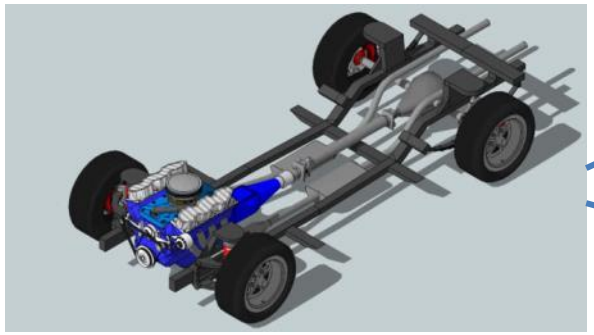
NB-IoT





LTE Cat-M1, NB-IoT 비유

LTE MBB



LTE Network

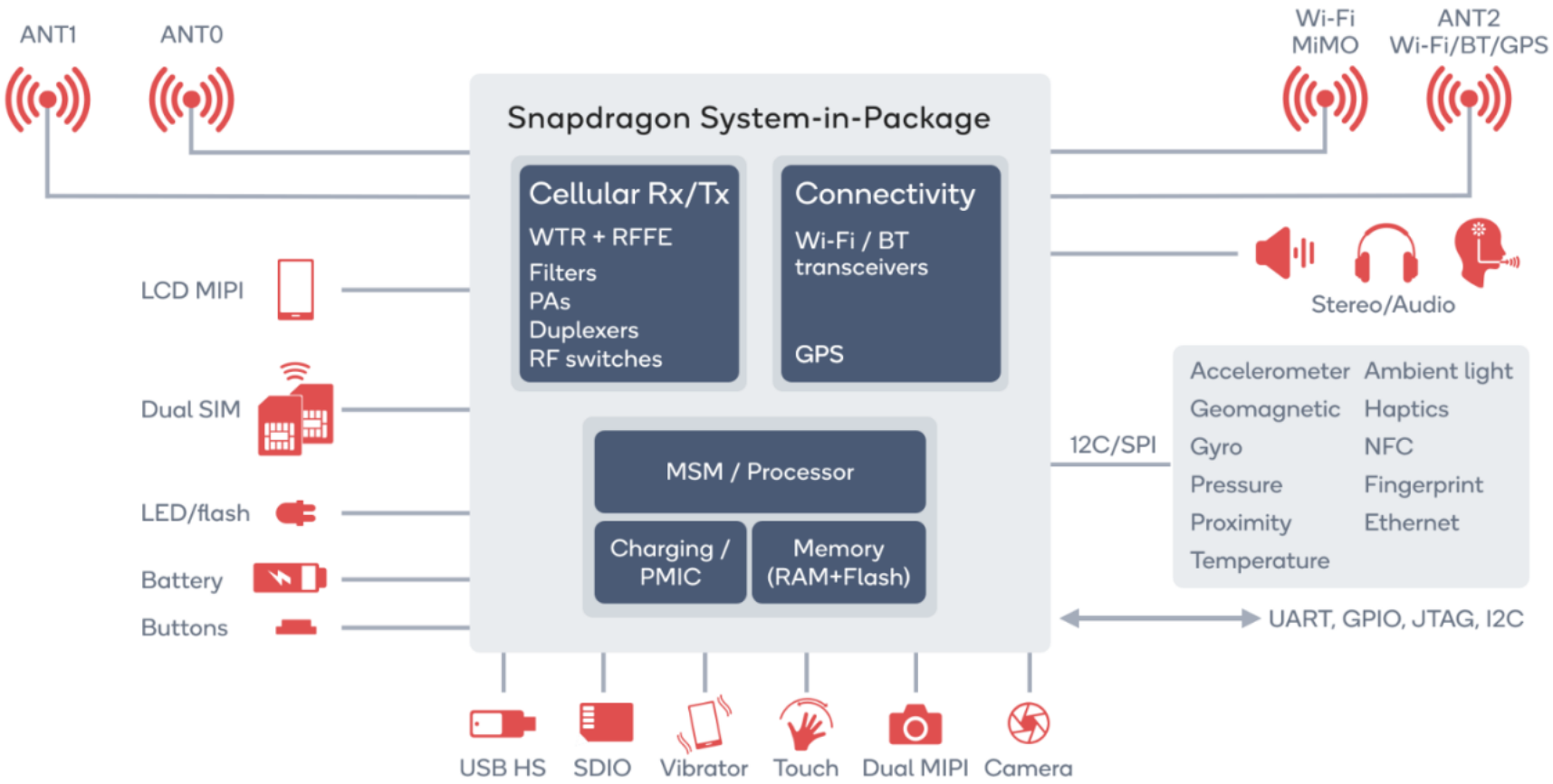
LTE Cat-M1

LTE Network(NB-IoT)

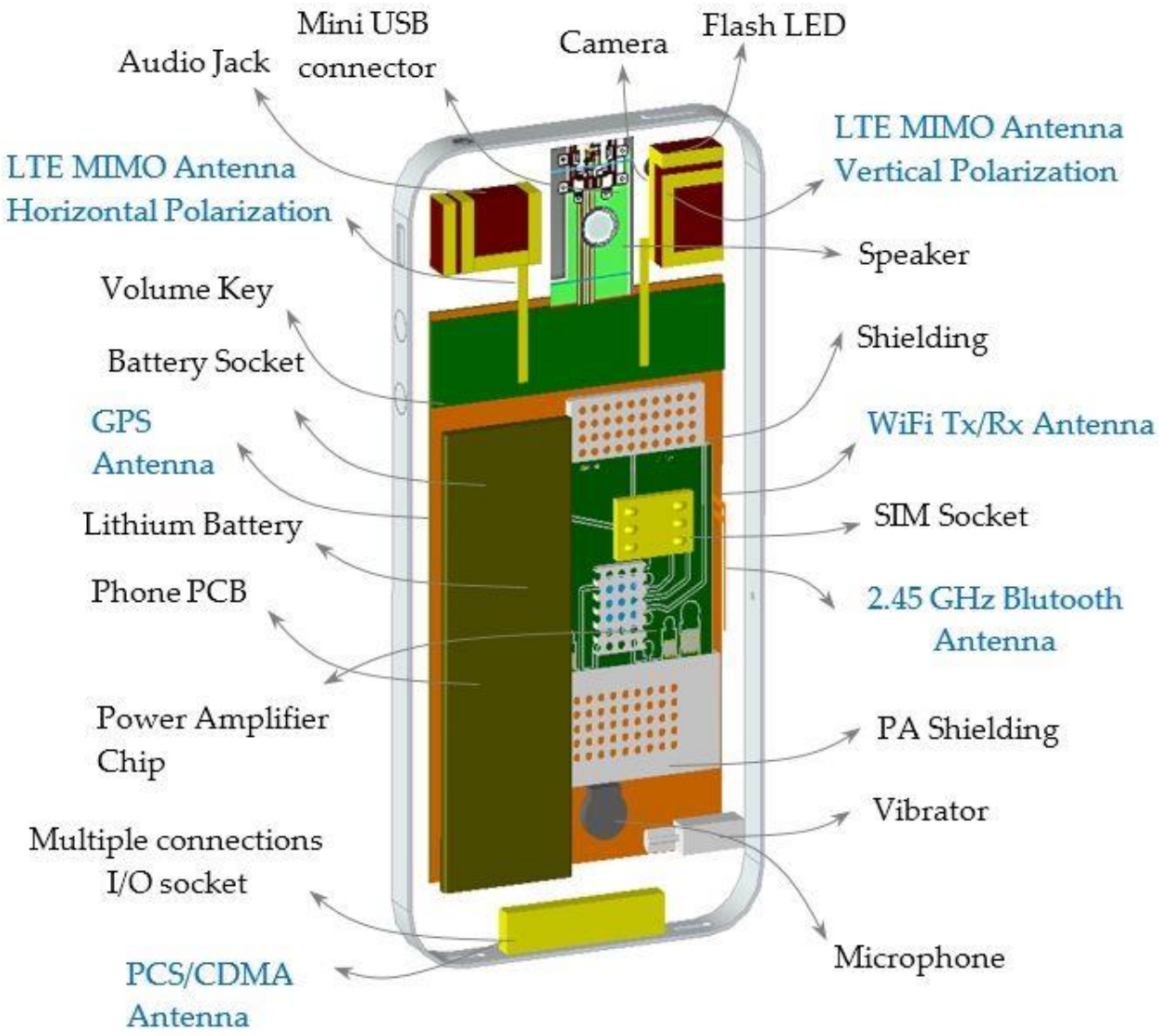
LTE NB-IoT

이동통신 단말기

단말기 전체 구조


ANT1
ANT0
Wi-Fi MiMO
ANT2 Wi-Fi/BT/GPS
Snapdragon System-in-Package
Cellular Rx/Tx
WTR + RFFE
Filters
PAs
Duplexers
RF switches
Connectivity
Wi-Fi / BT transceivers
GPS
MSM / Processor
Charging / PMIC
Memory (RAM+Flash)
LCD MIPI
Dual SIM
LED/flash
Battery
Buttons
Stereo/Audio
12C/SPI
Accelerometer
Ambient light
Geomagnetic
Haptics
Gyro
NFC
Pressure
Fingerprint
Proximity
Ethernet
Temperature
UART, GPIO, JTAG, I2C
USB HS
SDIO
Vibrator
Touch
Dual MIPI
Camera

단말기 부품 예

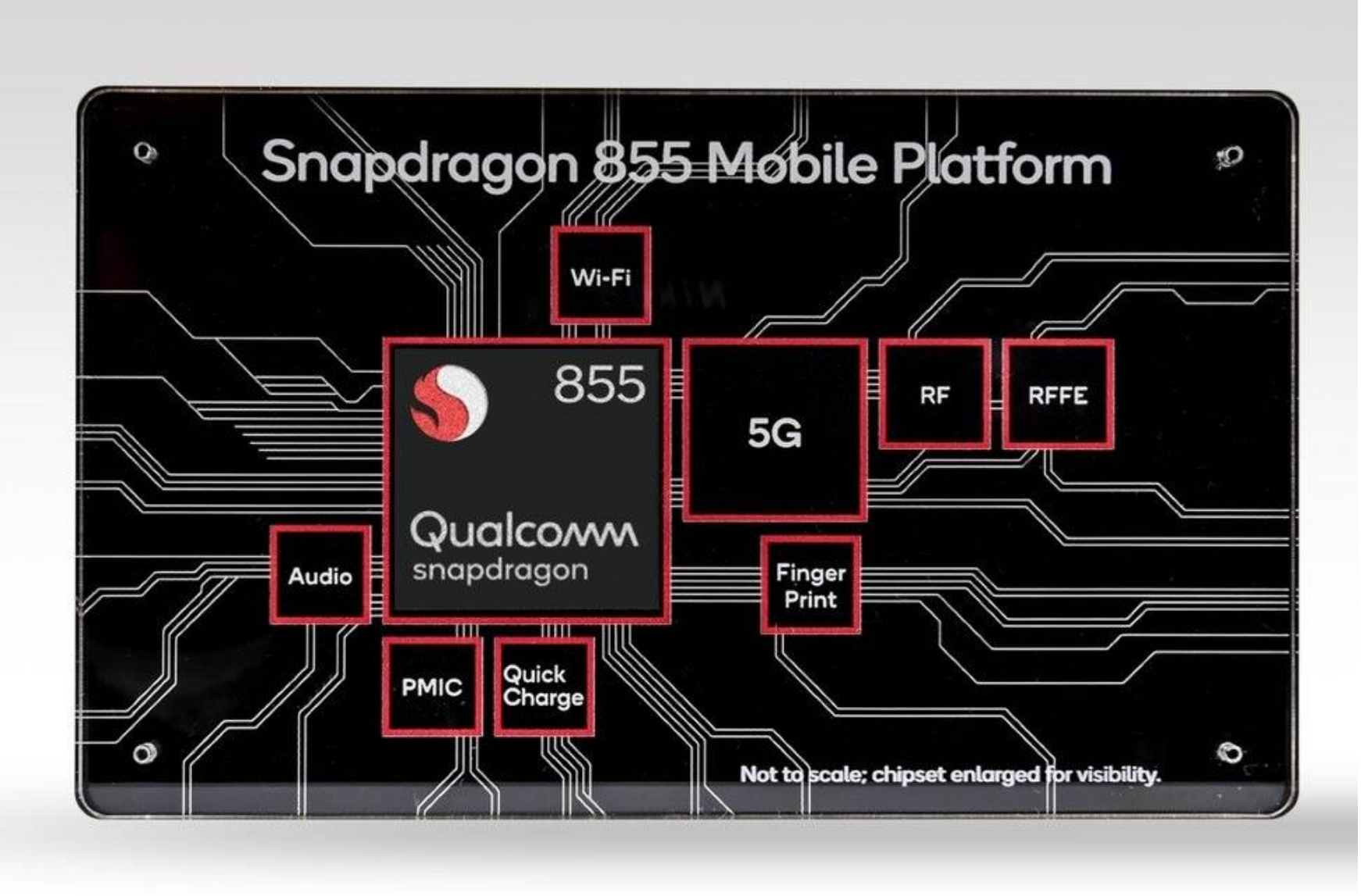

Audio Jack
Mini USB connector
Camera
Flash LED
LTE MIMO Antenna Horizontal Polarization
LTE MIMO Antenna Vertical Polarization
Speaker
Volume Key
Battery Socket
Shielding
GPS Antenna
WiFi Tx/Rx Antenna
Lithium Battery
SIM Socket
Phone PCB
2.45 GHz Blutooth Antenna
Power Amplifier Chip
PA Shielding
Vibrator
Multiple connections I/O socket
Microphone
PCS/CDMA Antenna

Mobile AP 예

칩 제조사	삼성	애플	화웨이	퀄컴
모바일 AP 칩셋명	 Exynos 9, 9820	 A12, BIONIC	 Kirin, 980	 Snapdragon, 855
CPU	8 Core	6 Core	8 Core	8 Core
클럭	2.73 GHz + 2.31 GHz + 1.95 GHz	2.5GHz	2.8GHz	2.4GHz
GPU	ARM Mali-G76 MP12	Apple G11P MP4	ARM Mali-G76 MP12	Adreno 640
NPU	통합	8 Core	Dual	통합
메모리	듀얼채널 LPDDR4X	듀얼채널 LPDDR4X	듀얼채널 LPDDR4X	듀얼채널 LPDDR4X
주요기기	갤럭시 S10e, S10, S10+, S10 5G	아이폰 Xs, XR, XS Max	화웨이 아너 V20	LG V50

* AP: Application Processor

Qualcomm Snapdragon 855

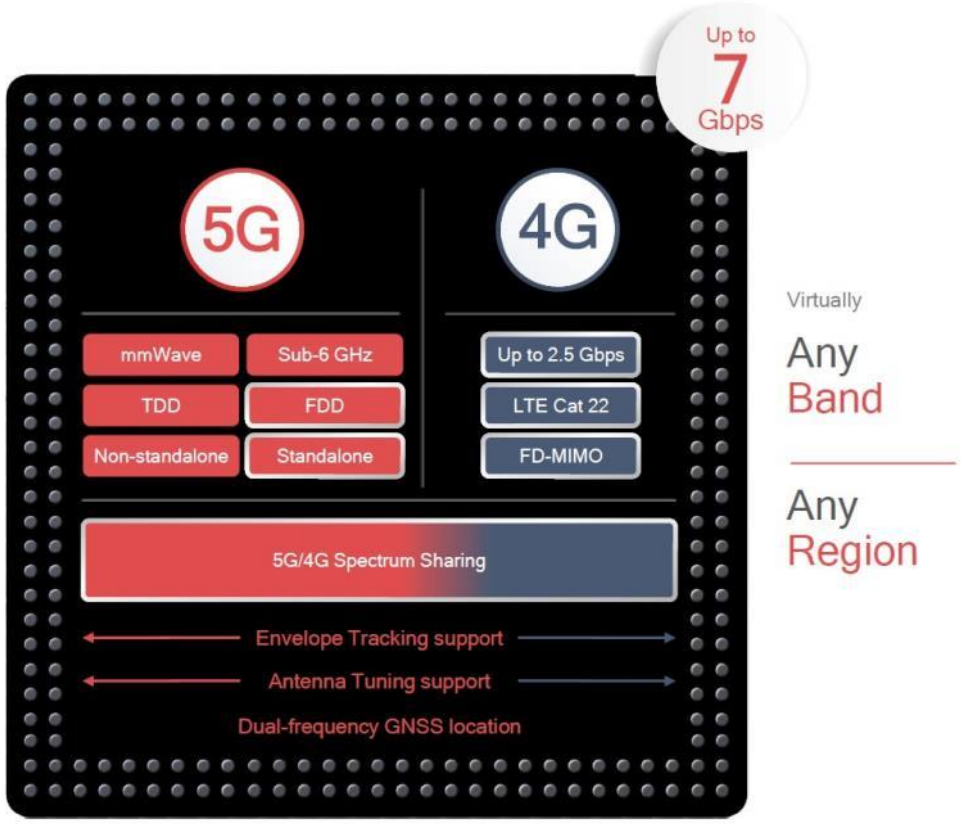


Qualcomm Snapdragon X55

Qualcomm snapdragon X55 5G modem

7nm single-chip

5G to 2G modem

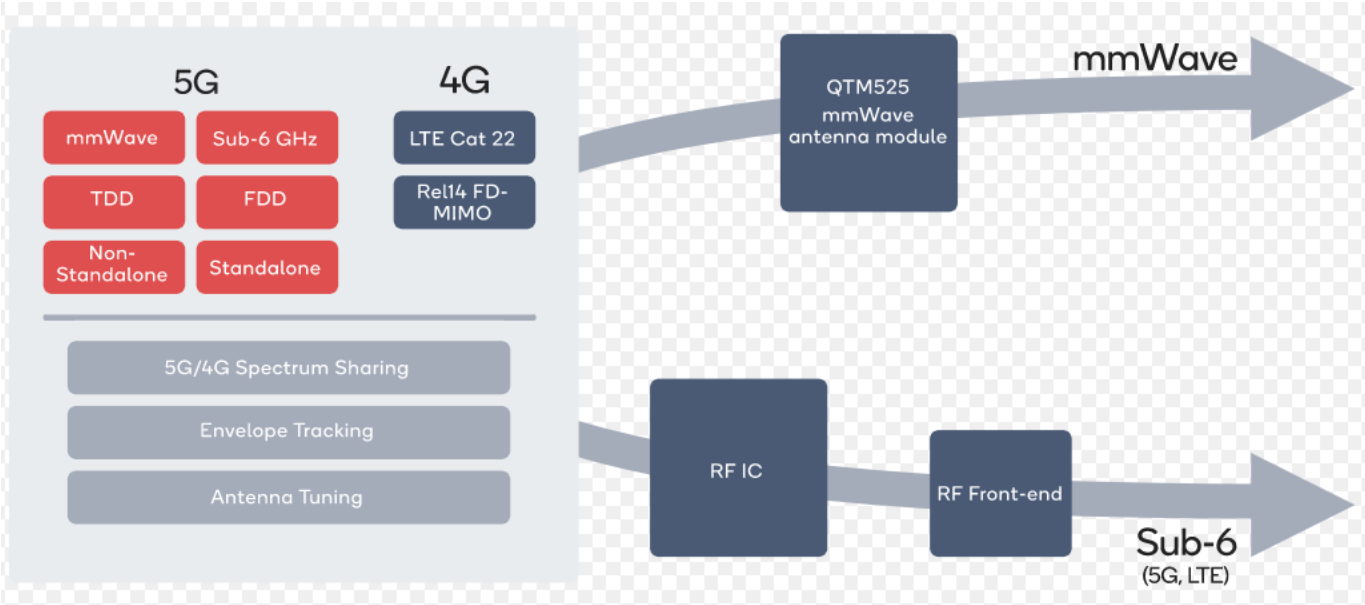


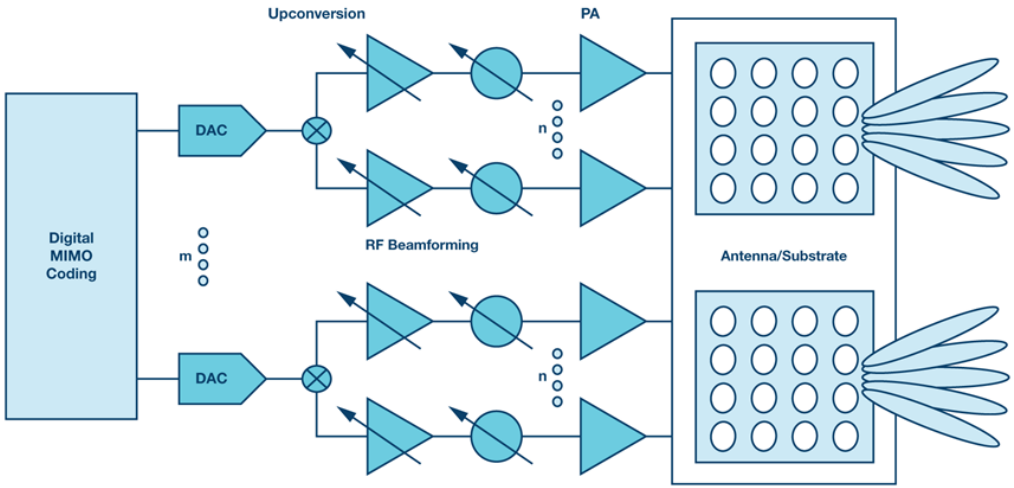
Virtually Any Band

Any Region

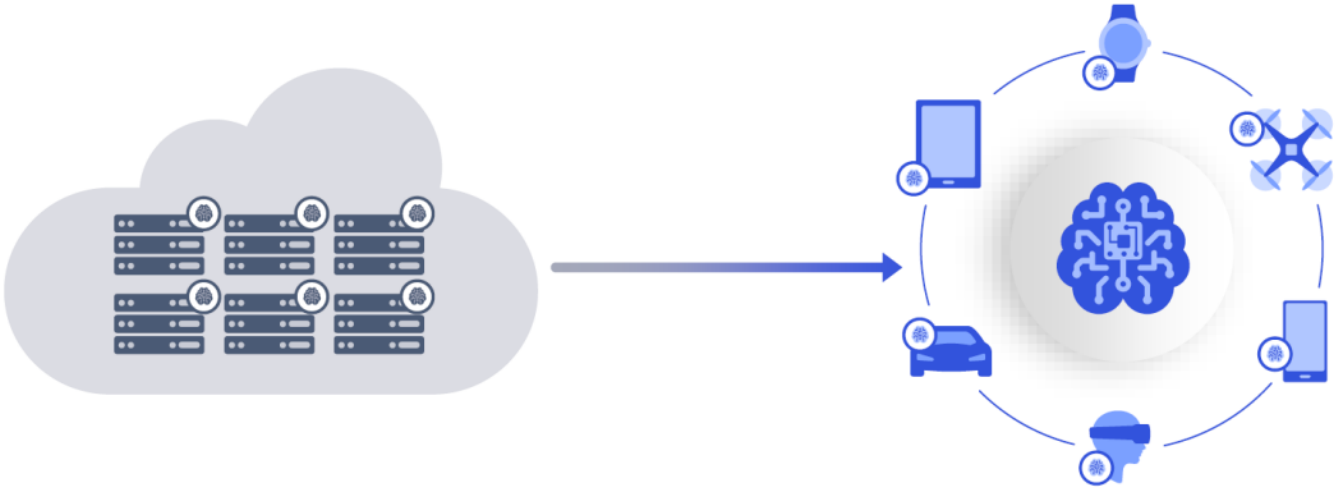
*Spectrum sharing, envelope tracking and antenna tuning apply to sub-6 GHz spectrum only

5G 단말기 – mmWave, MIMO



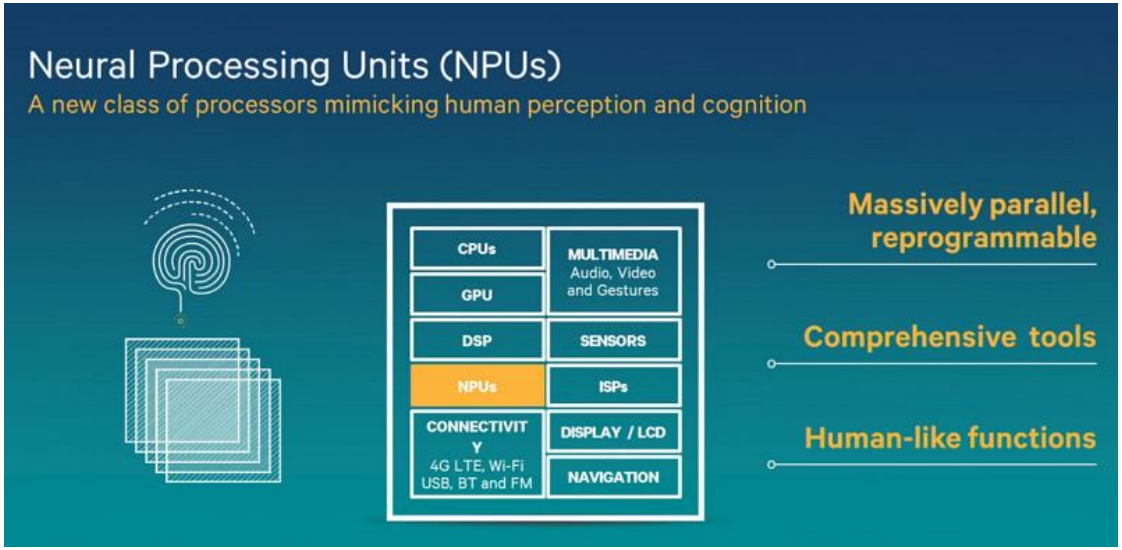


AI on Device



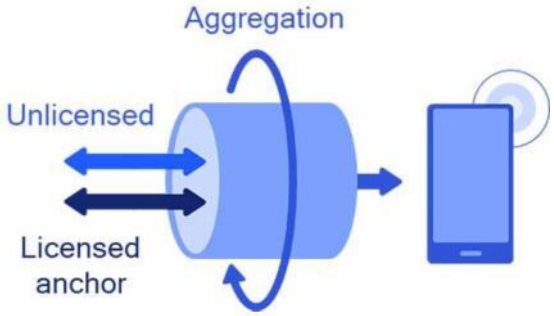
Server/Cloud
Training
Execution/Inference

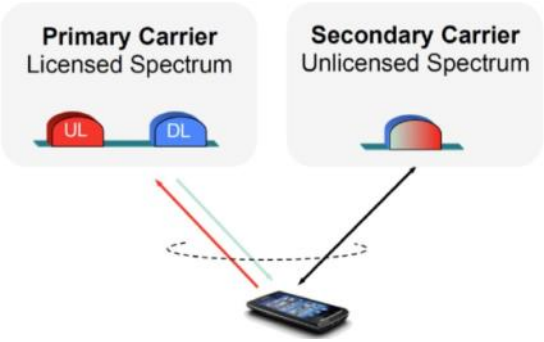
Devices
Execution/Inference
Training (emerging)

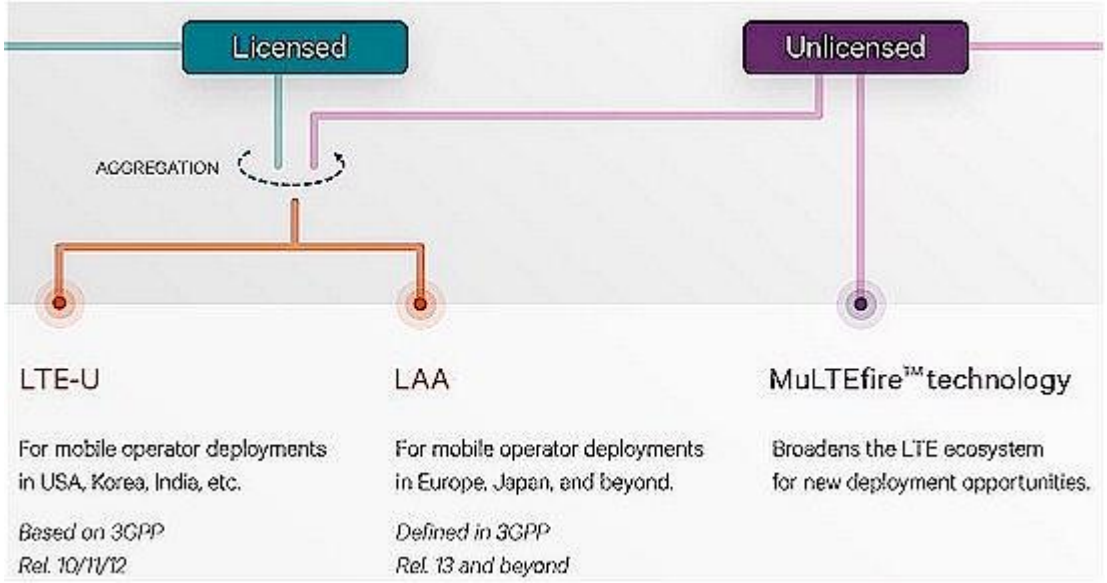


기타 무선망

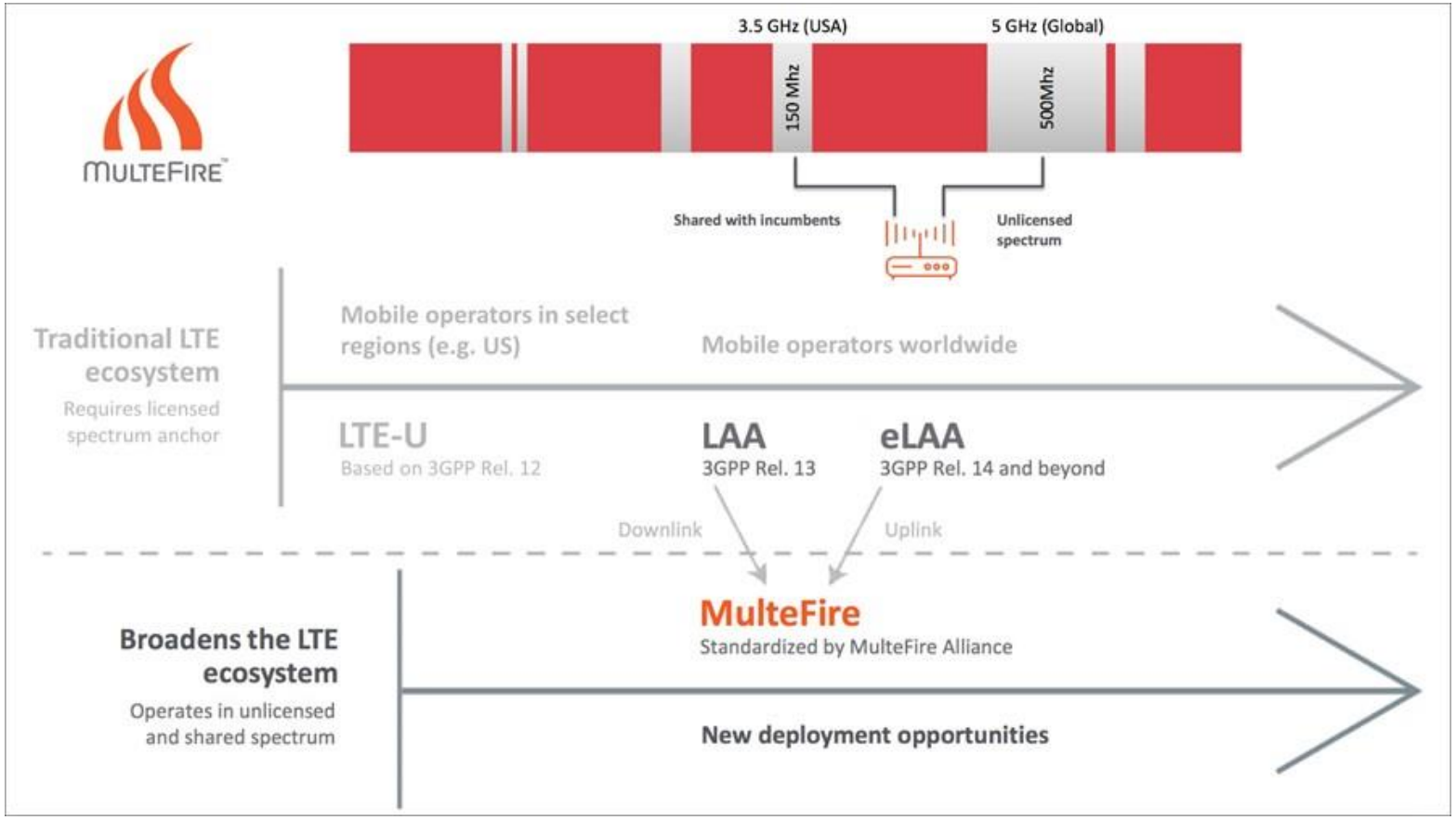
Aggregation with Unlicensed Spectrum



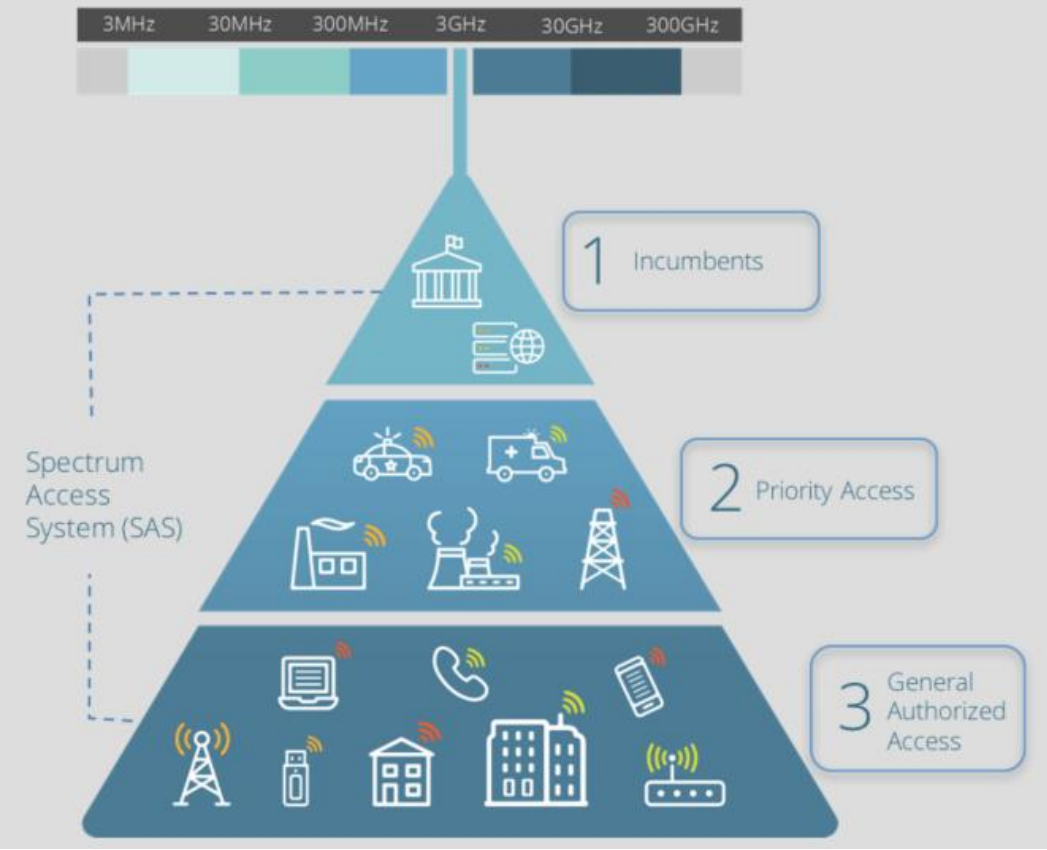




MulteFire

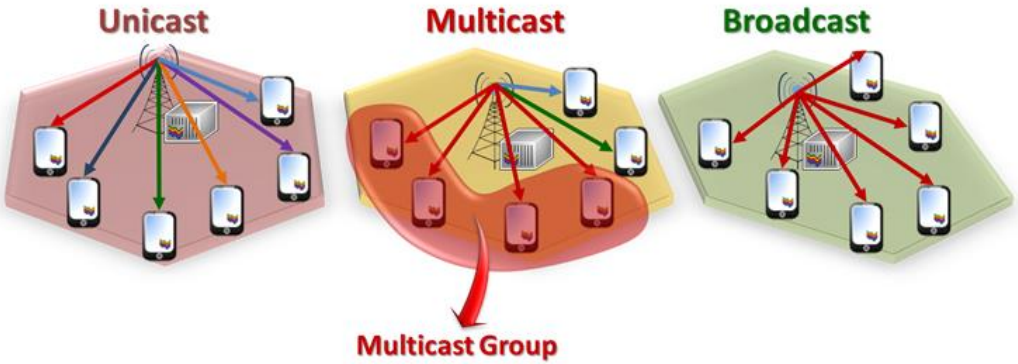

MULTEFIRE
3.5 GHz (USA)
5 GHz (Global)
150 Mhz
500Mhz
Shared with incumbents
Unlicensed spectrum
Traditional LTE ecosystem
Requires licensed spectrum anchor
Mobile operators in select regions (e.g. US)
Mobile operators worldwide
LTE-U
Based on 3GPP Rel. 12
LAA
3GPP Rel. 13
eLAA
3GPP Rel. 14 and beyond
Downlink
Uplink
MulteFire
Standardized by MulteFire Alliance
Broadens the LTE ecosystem
Operates in unlicensed and shared spectrum
New deployment opportunities

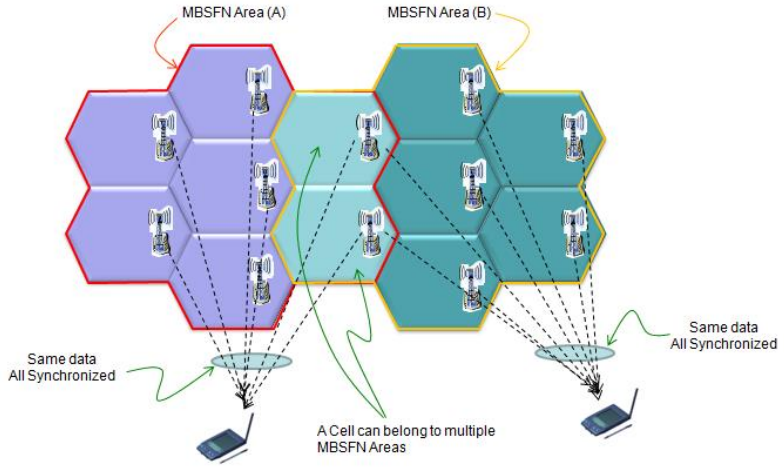
CBRS: Shared Spectrum



* CBRS: Citizens Broadband Radio Service

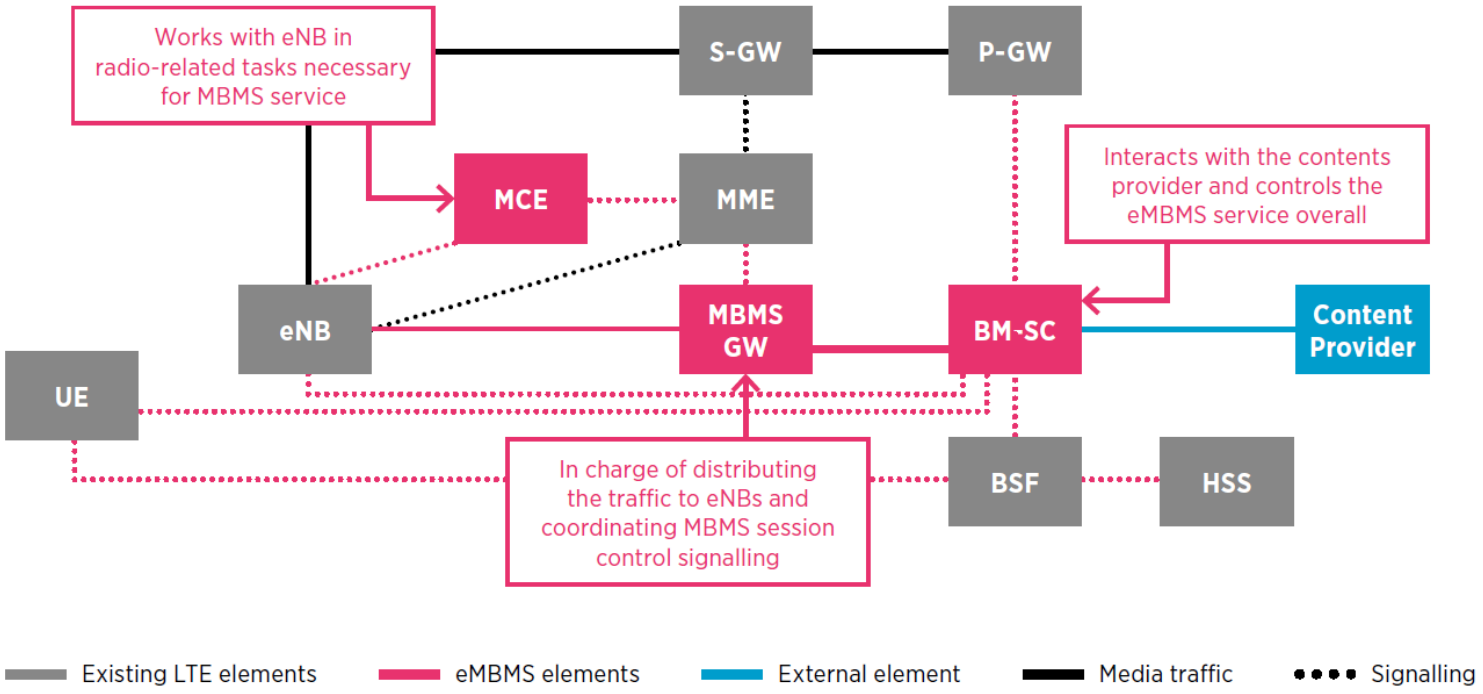
Cellular Broadcast Introduction





- 이동통신망을 활용한 방송서비스 기본 개념은 PTM(Point-To-Multipoint)
- eMBMS(ehanced Multimedia Broadcast Multicast Services)
  - 방송 전용 채널 사용
- MBSFN(MBMS Single Frequency Network) 기술 필요
- LTE에 eMBMS가 정의되었으나 사용되는 사례를 많지 않음
- 3GPP Release 15에 상용 가능한 수준으로는 정의되어 있지 않음. Release 16에 정의 예정

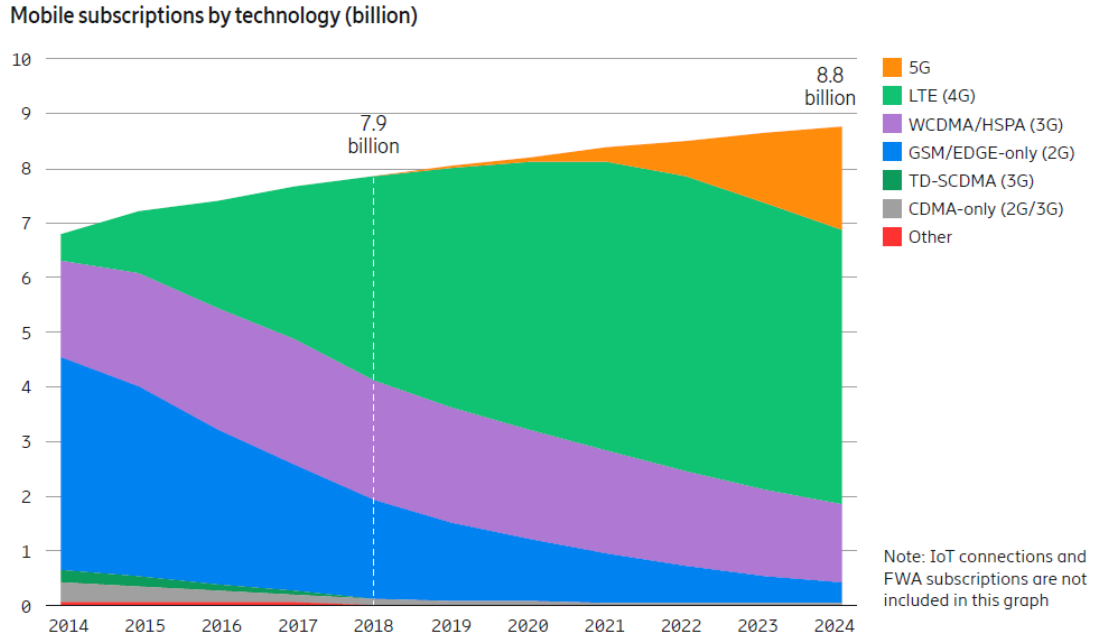
eMBMS Network Architecture

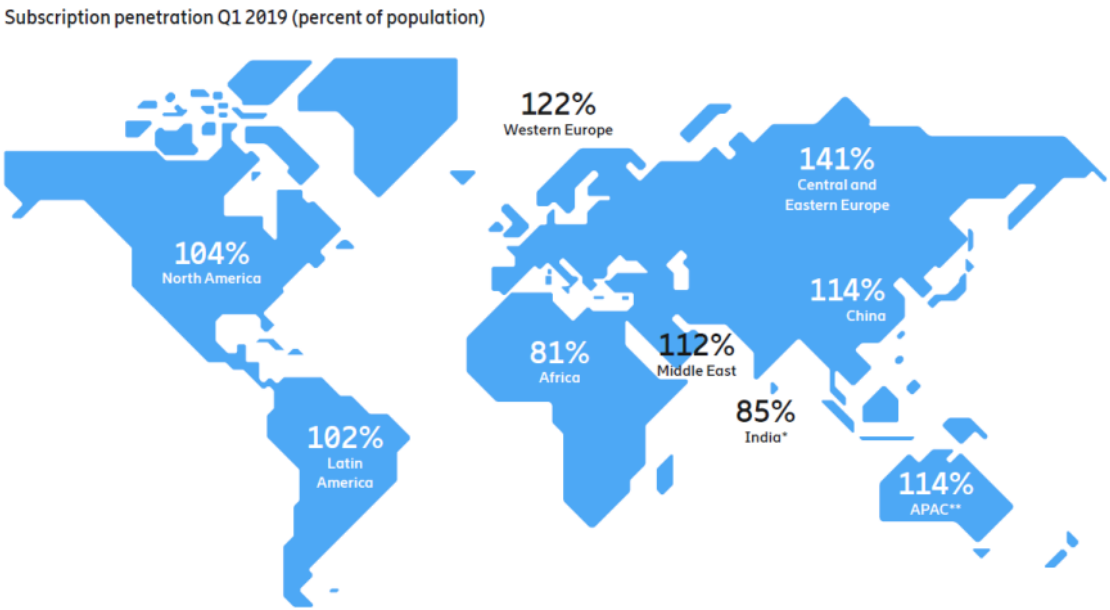


- BM-SC(Broadcast Multicast Service Centre): eMBMS 에서 서비스 관리, 방송 송출 등
- MBMS-GW: BM-SC 컨텐츠를 LTE/NR 망으로 전달
- MCE: Multicell Coordination Entity: LTE 무선 프로토콜에 eMBMS 정보 추가

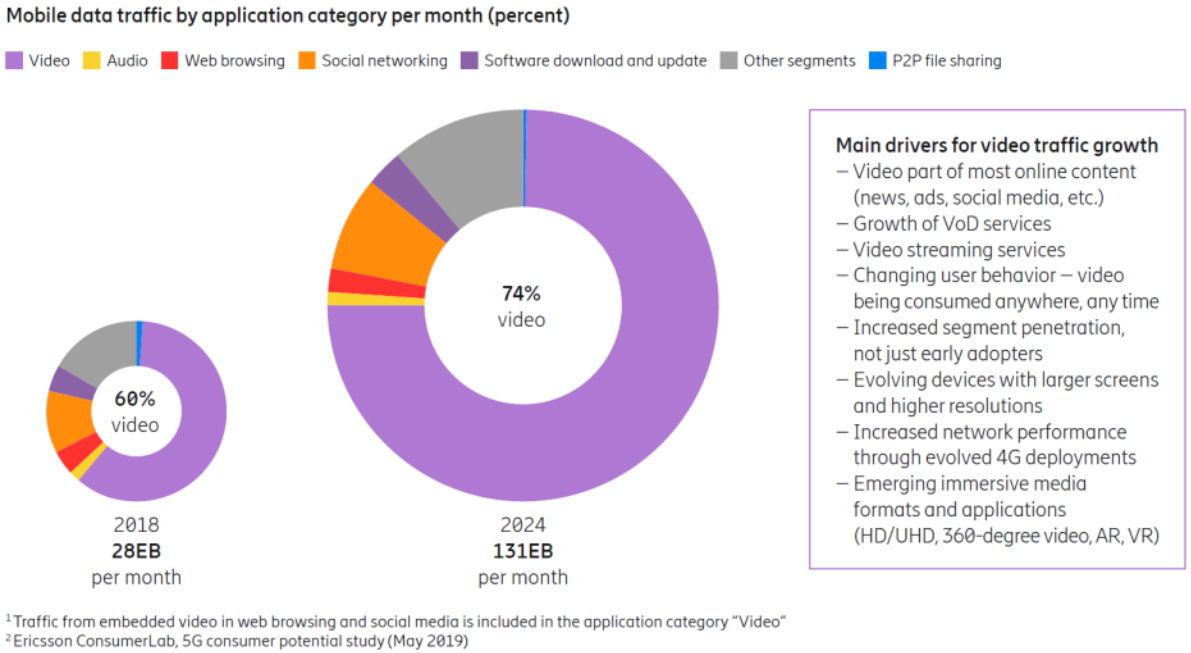
시장, Eco System

기술 별 가입자수, Penetration Rate

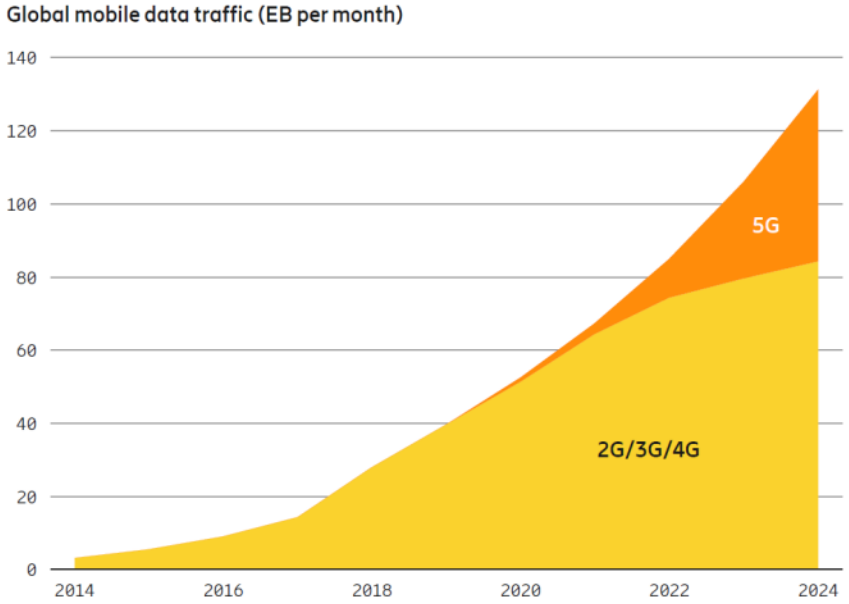




Mobile Traffic 예측



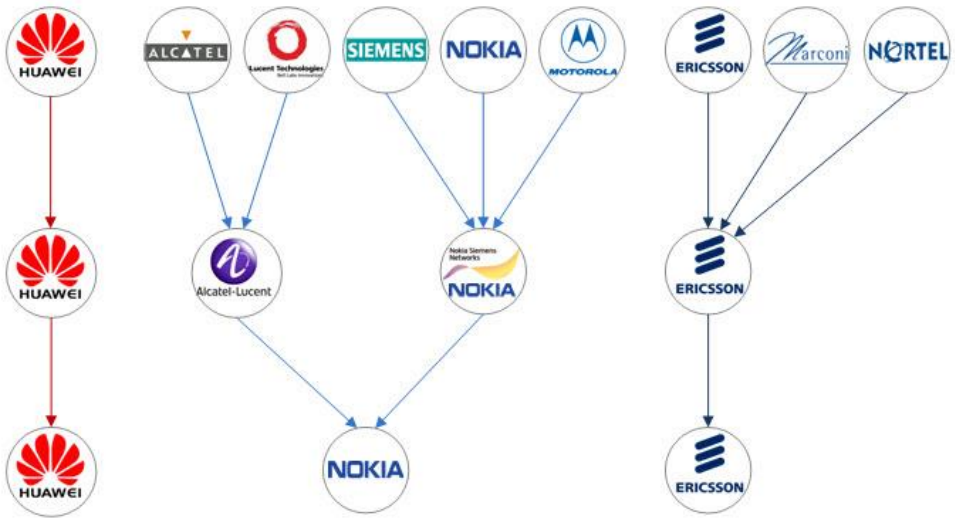
[1] Traffic from embedded video in web browsing and social media is included in the application category "Video"
[2] Ericsson ConsumerLab, 5G consumer potential study (May 2019)



주요 이동통신 사업자

Rank	Company	Total subscribers (in millions)
1	China Mobile	851.2
2	Vodafone	469.7
3	Airtel	348.1
4	América Móvil	280.6
5	Telefónica	276.5
6	China Unicom	265.1
7	MTN Group	234.7
8	China Telecom	216.8
9	Telenor	214.0
10	VimpelCom	205.5

주요 이동통신 장비, 단말기 제조사



5G 이동통신 서비스

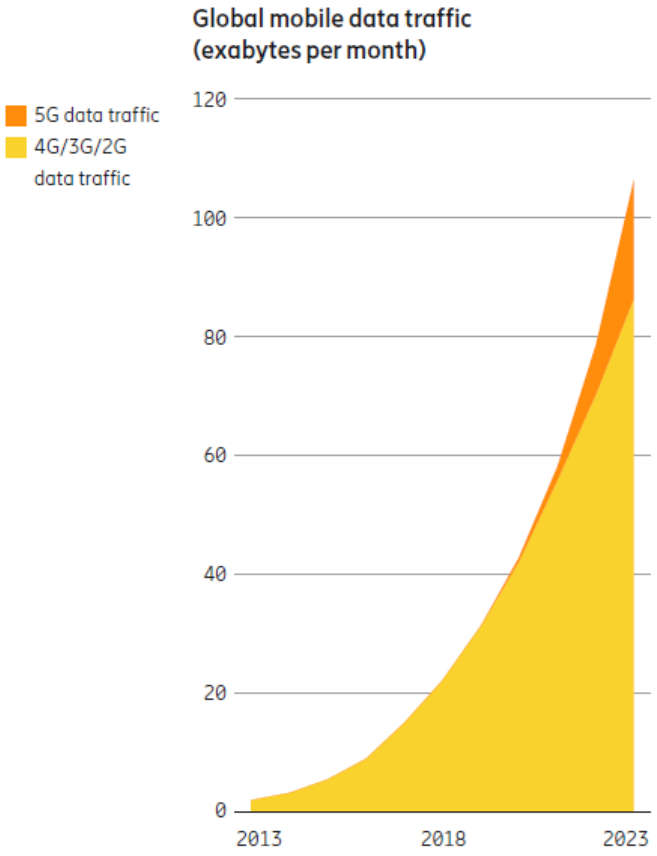
Hyun-Wook Kim

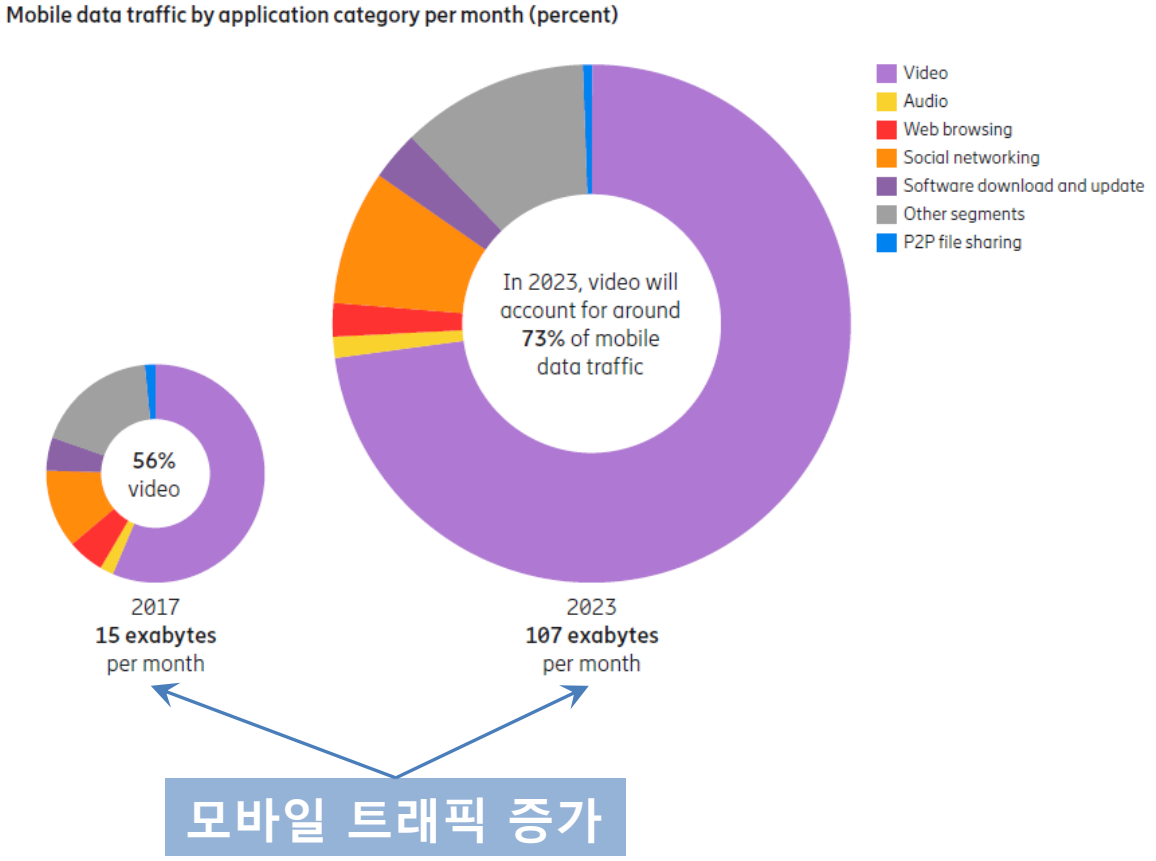
hw.kim@sk.com
hwkim7@gmail.com

목차

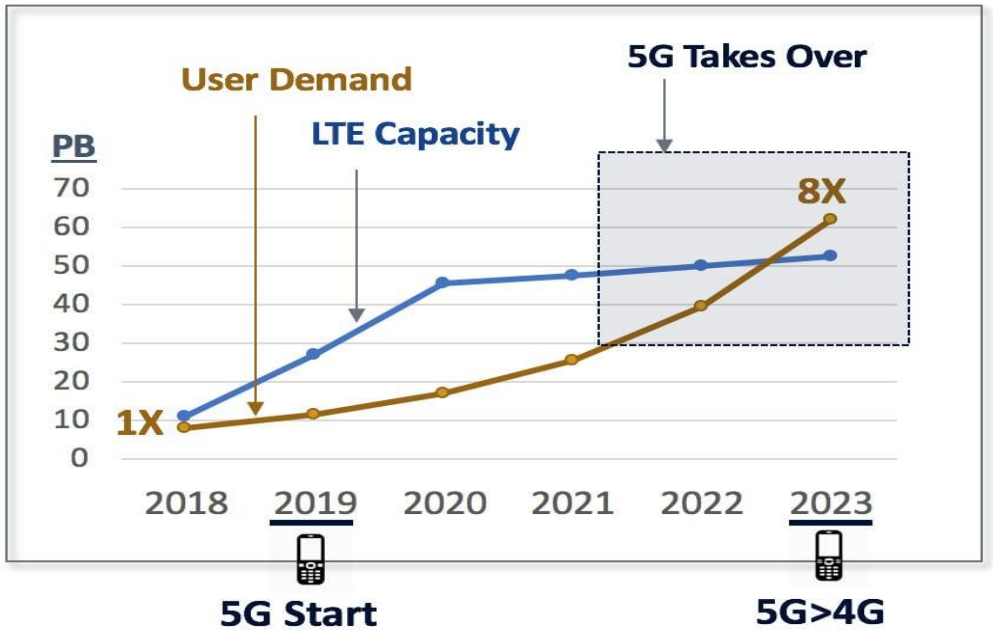
배경

5G 기술정의 배경(1)

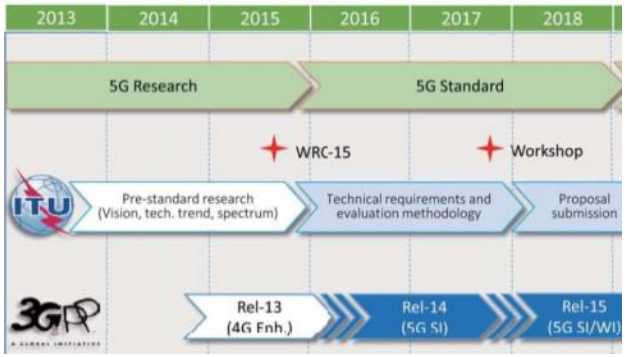

Global mobile data traffic
(exabytes per month)
5G data traffic
4G/3G/2G
data traffic
120
100
80
60
40
20
0
2013
2018
2023


Mobile data traffic by application category per month (percent)
Video
Audio
Web browsing
Social networking
Software download and update
Other segments
P2P file sharing
In 2023, video will account for around 73% of mobile data traffic
56% video
2017
15 exabytes
per month
2023
107 exabytes
per month
모바일 트래픽 증가

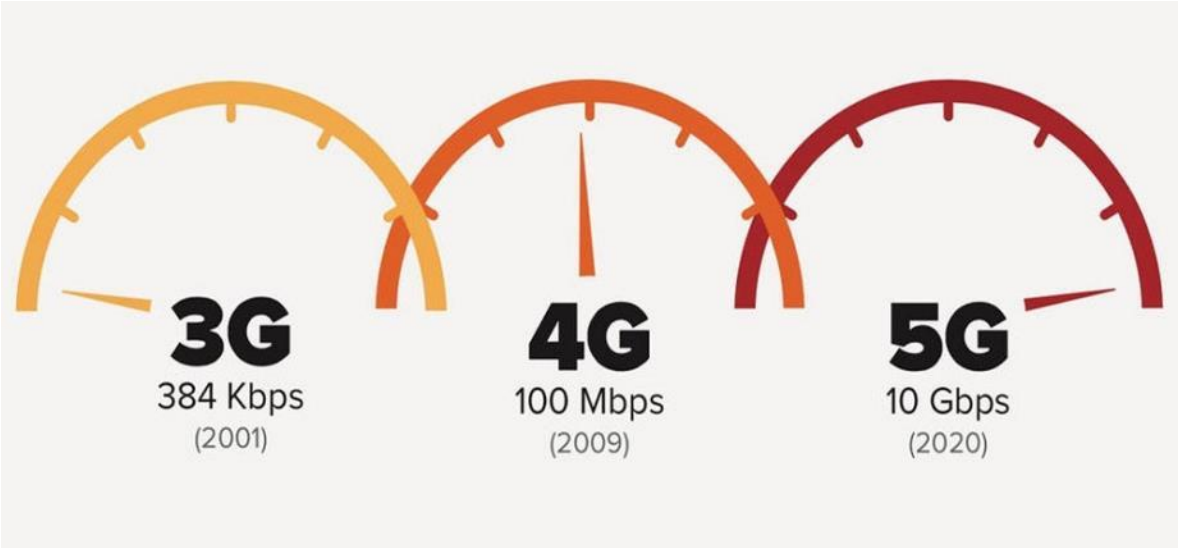
5G 기술정의 배경(2)

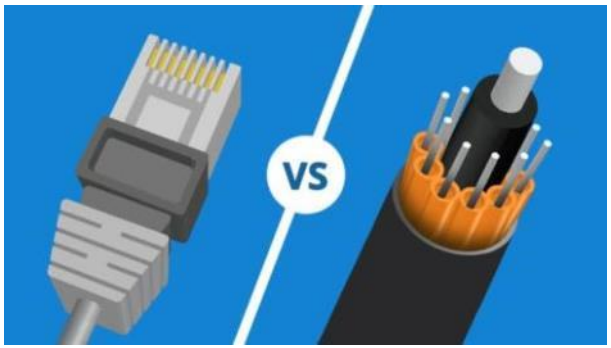


- 5G 기술을 정의하게 된 배경은 급증하는 모바일 트래픽 !
  - 모바일 트래픽이 급증하여 2022년에 4G망의 한계 초과
- 추가로 IoT, 초저지연 서비스 니즈 증가



5G 기술개발 방향, 전송속도 증대





4G ➔ 5G

R8, R9 | R10, R11, R12 | R13, R14 | R15…

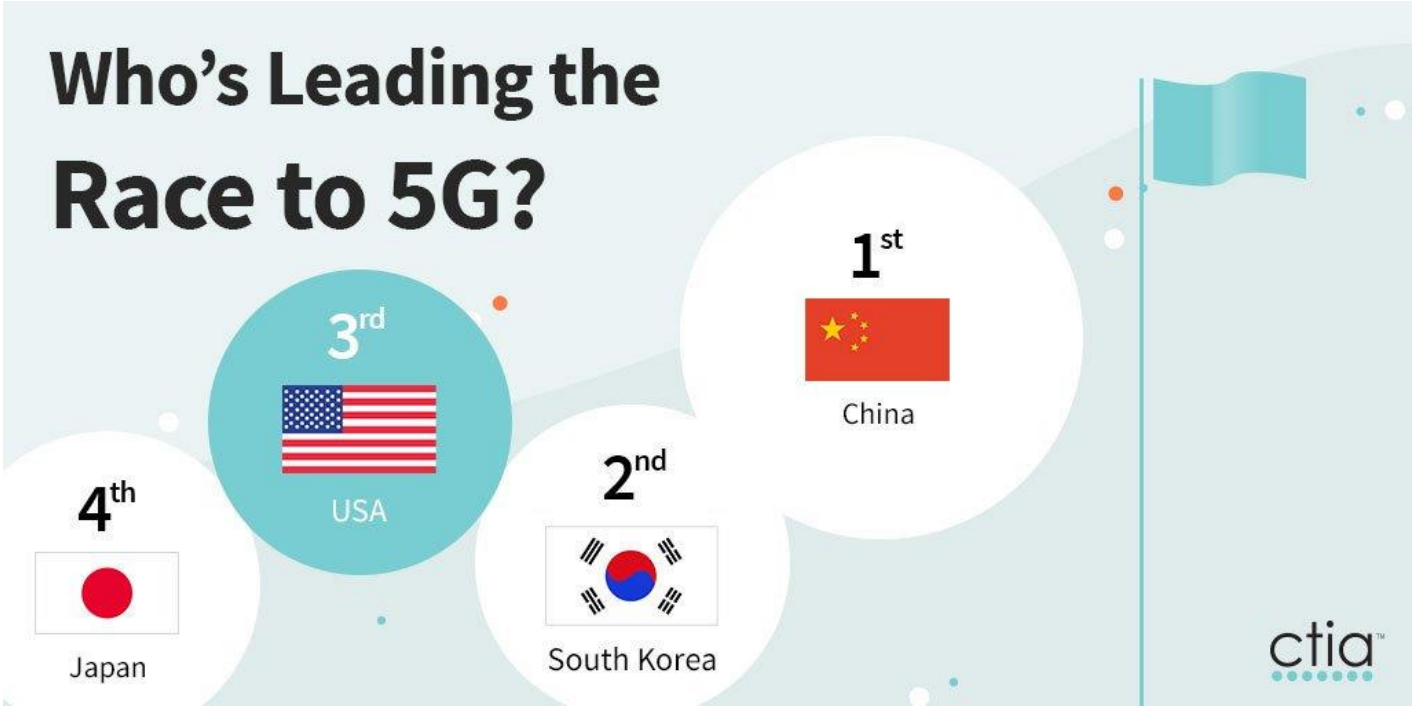
5G 특징(정책적 측면)

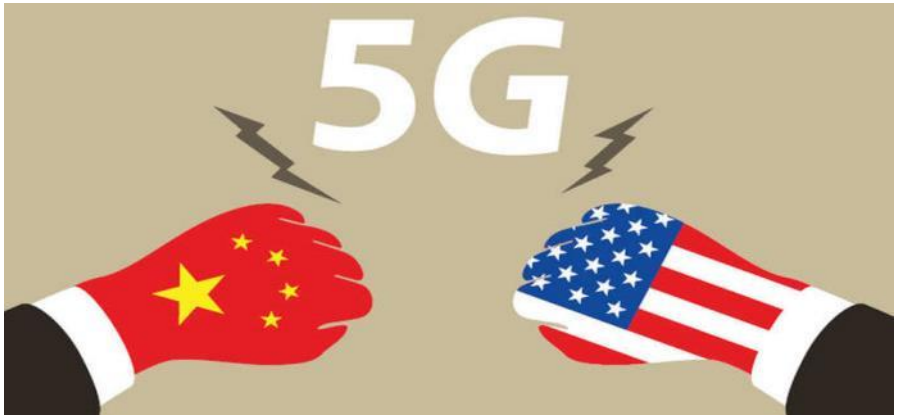
⇒ 개별 산업을 넘어 융합 생태계 육성이 중요

⇒ 표준을 주도한 국가와 기업의 영향력이 지속

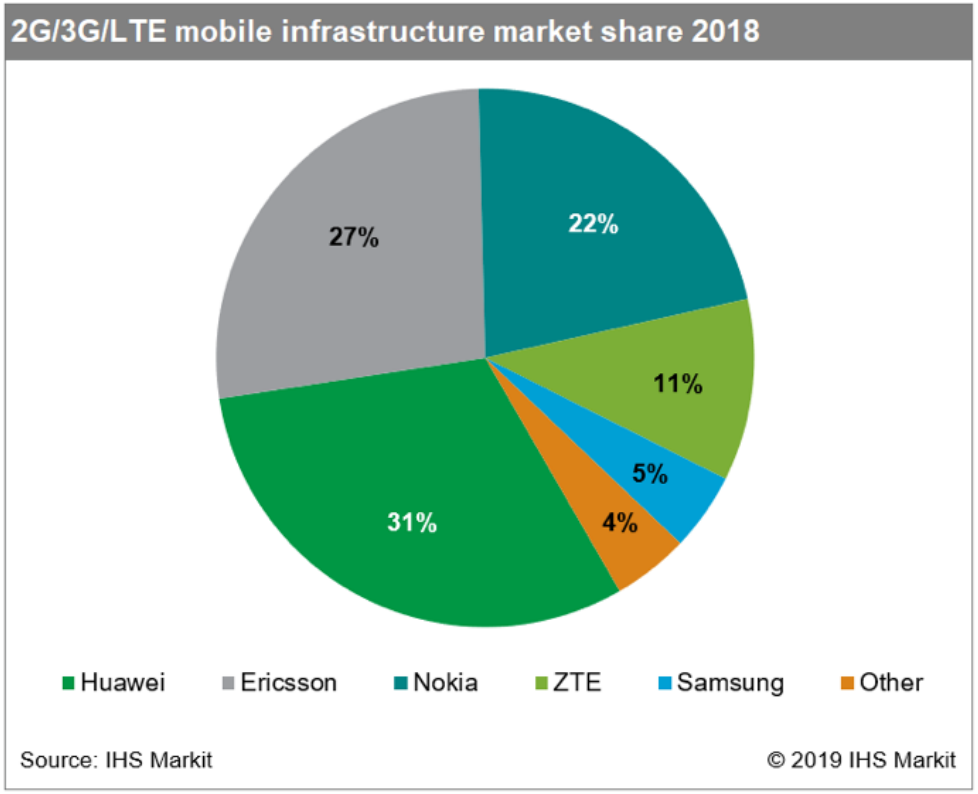
⇒ 국내에 조기 도입하고 확산시켜 국내 5G 기술과 서비스로 세계 시장 선점

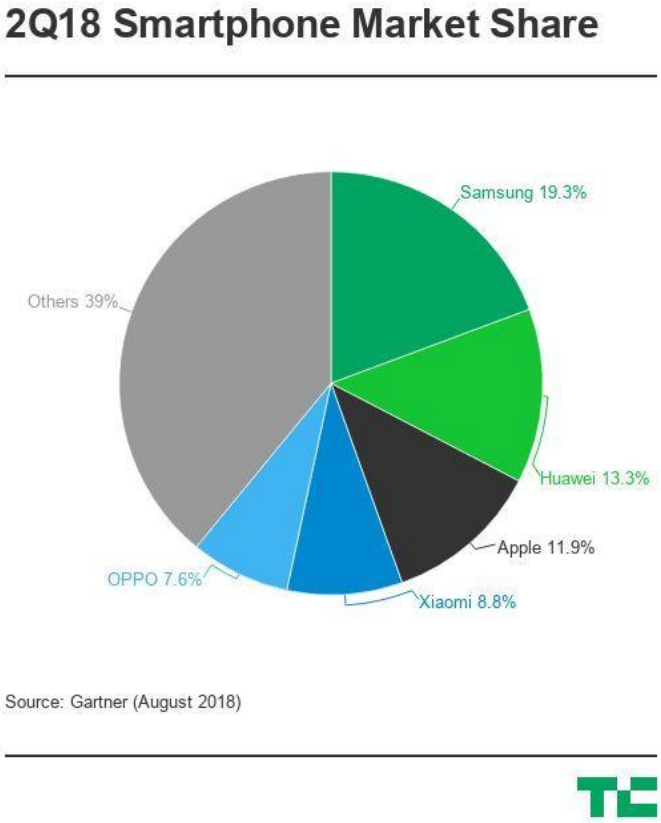
미국과 중국의 5G 경쟁


Who's Leading the
Race to 5G?
1st
China
2nd
South Korea
3rd
USA
4th
Japan
ctia

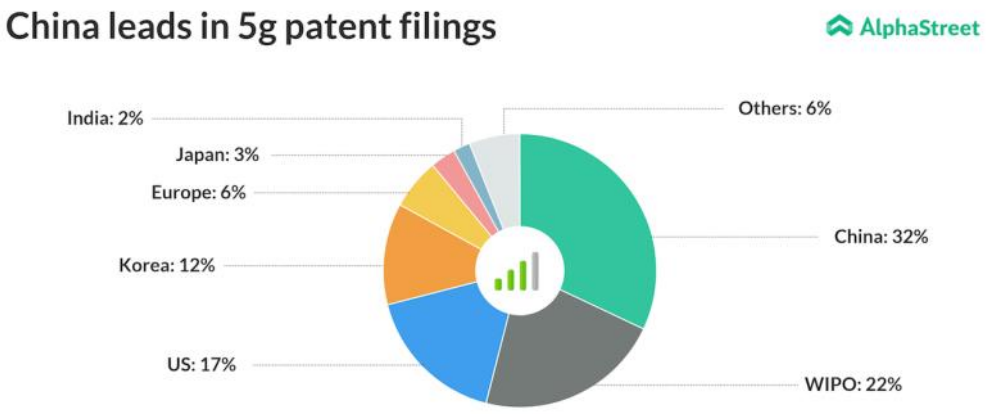

5G

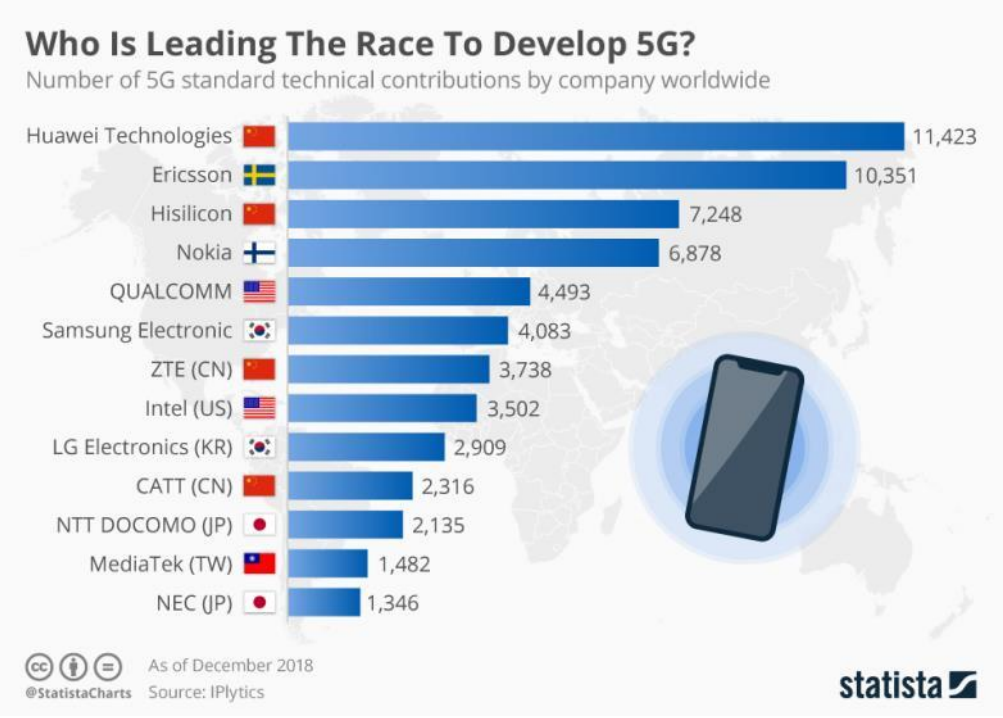
이동통신 장비, 단말기 시장 점유율(2018)



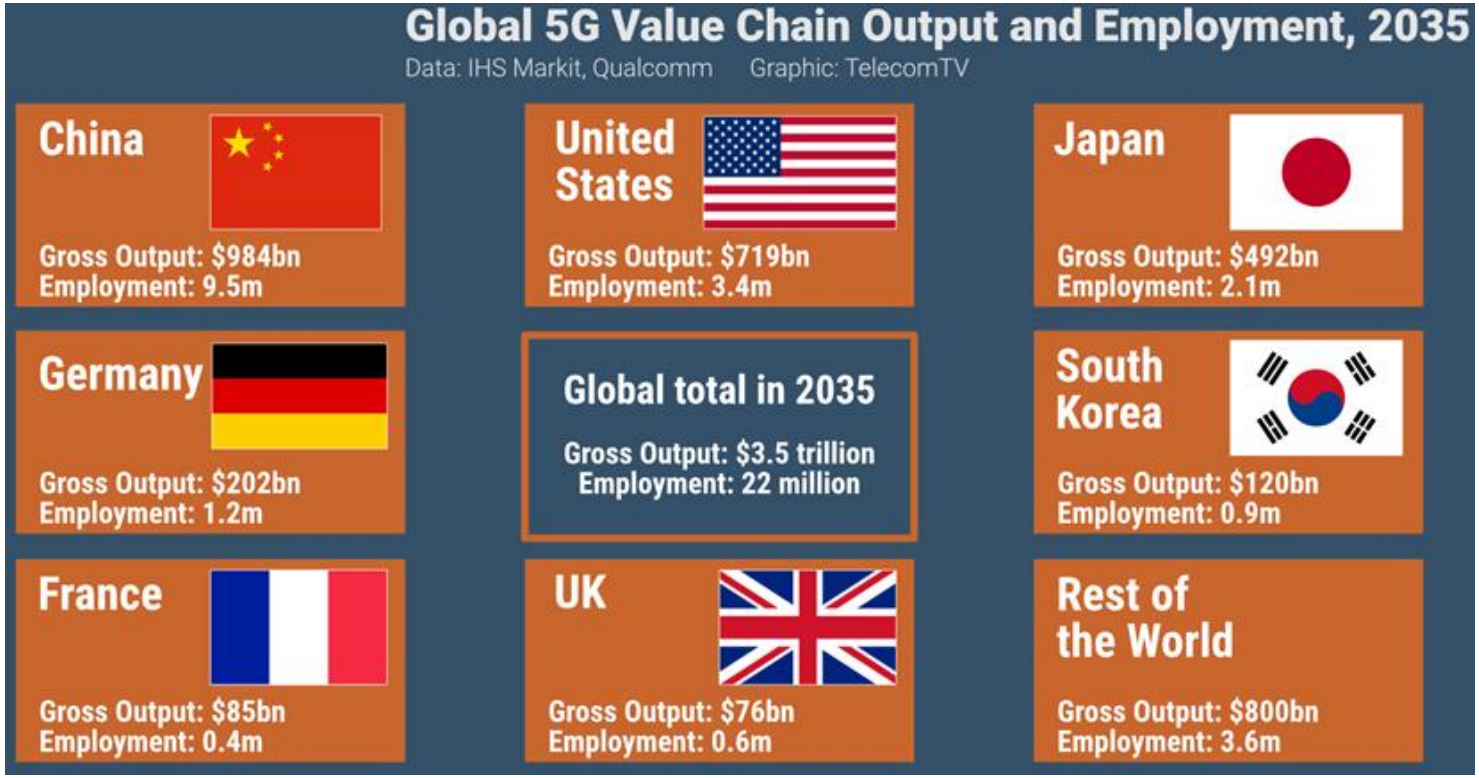


5G 특허와 표준화 기여 정도(2018년)

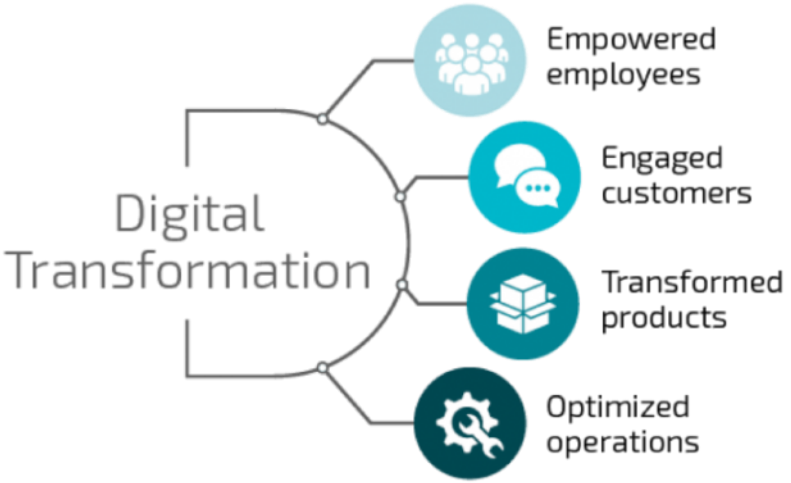


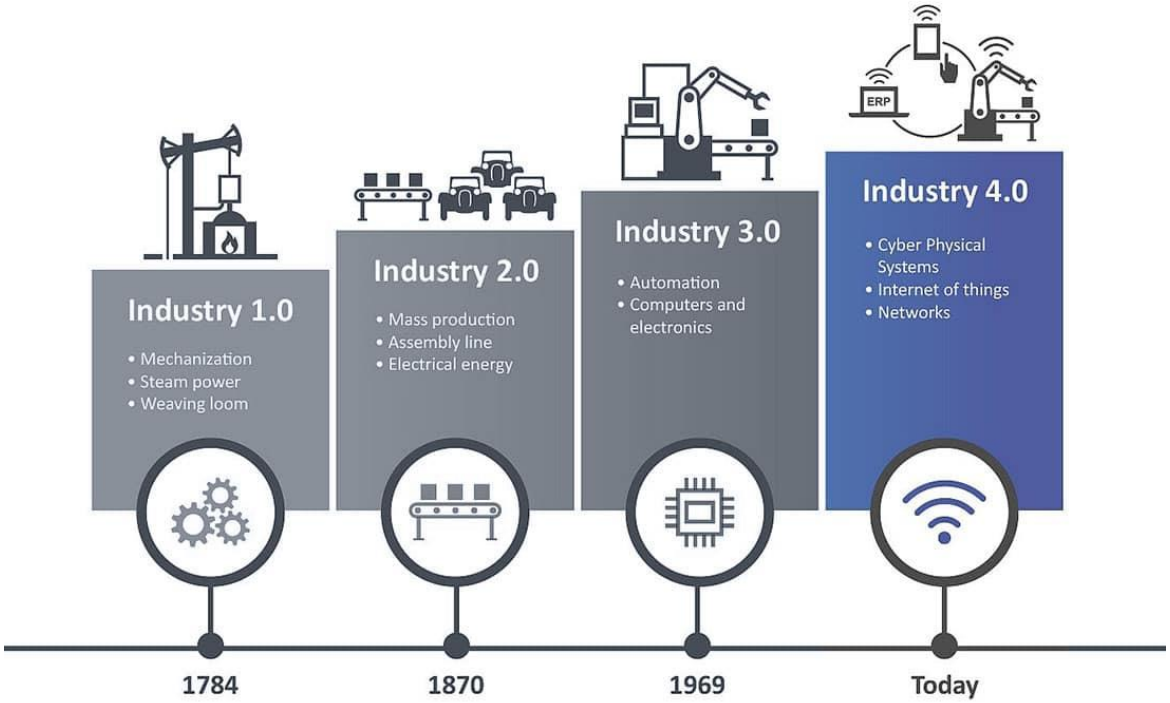


주요 국가의 5G 경제적 가치 예측

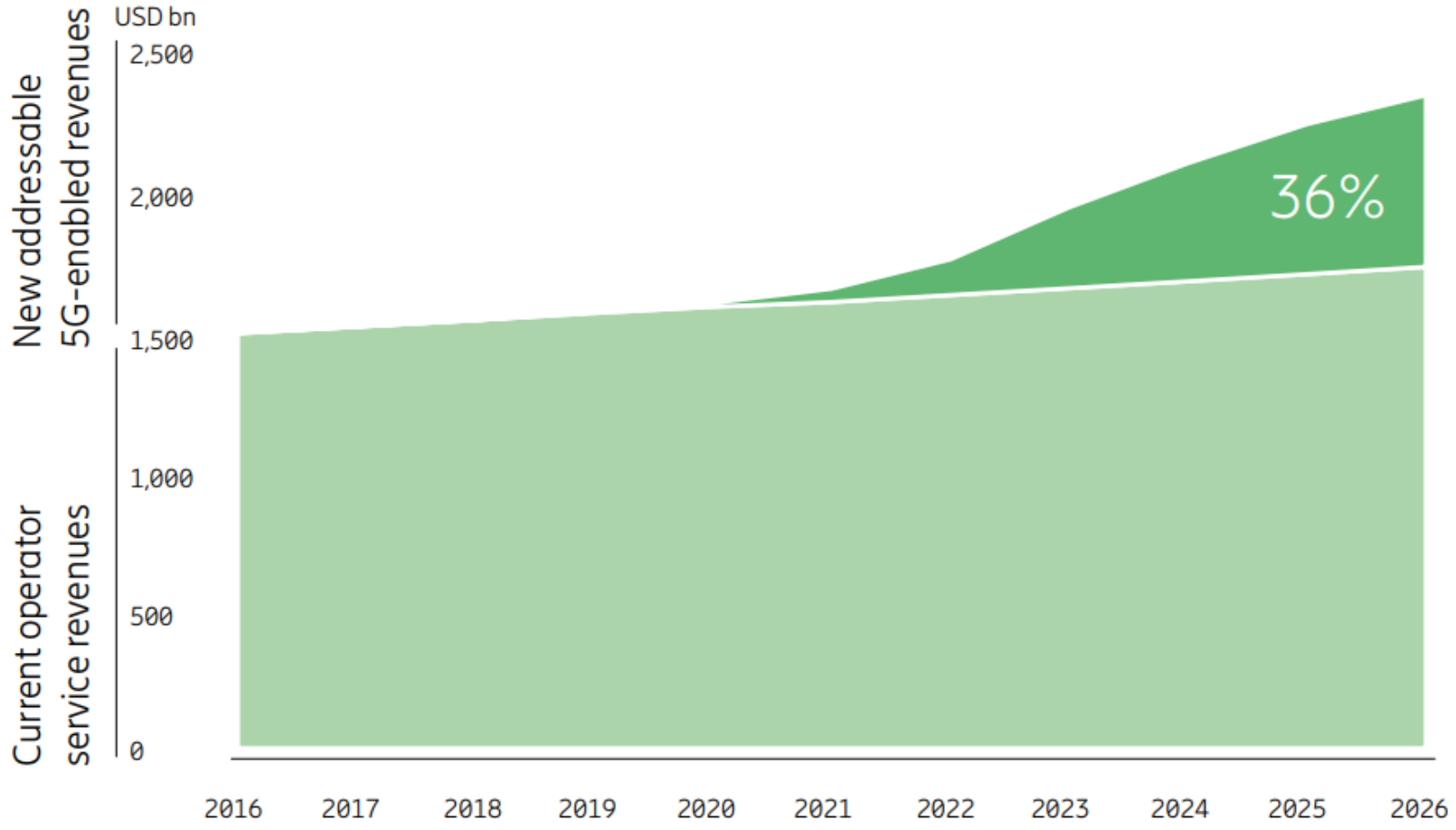


Digital Transformation, Industry 4.0

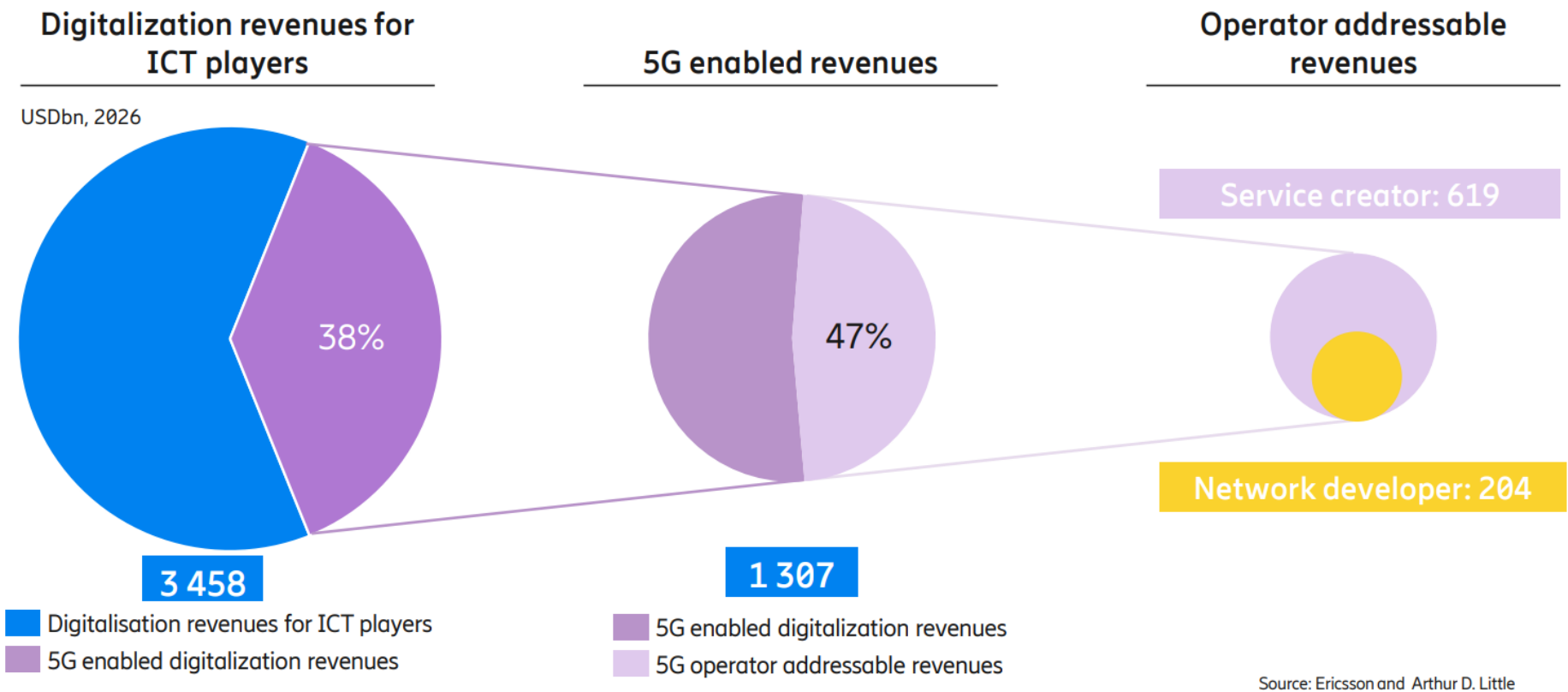




사업자 측면 수익 예측(1)

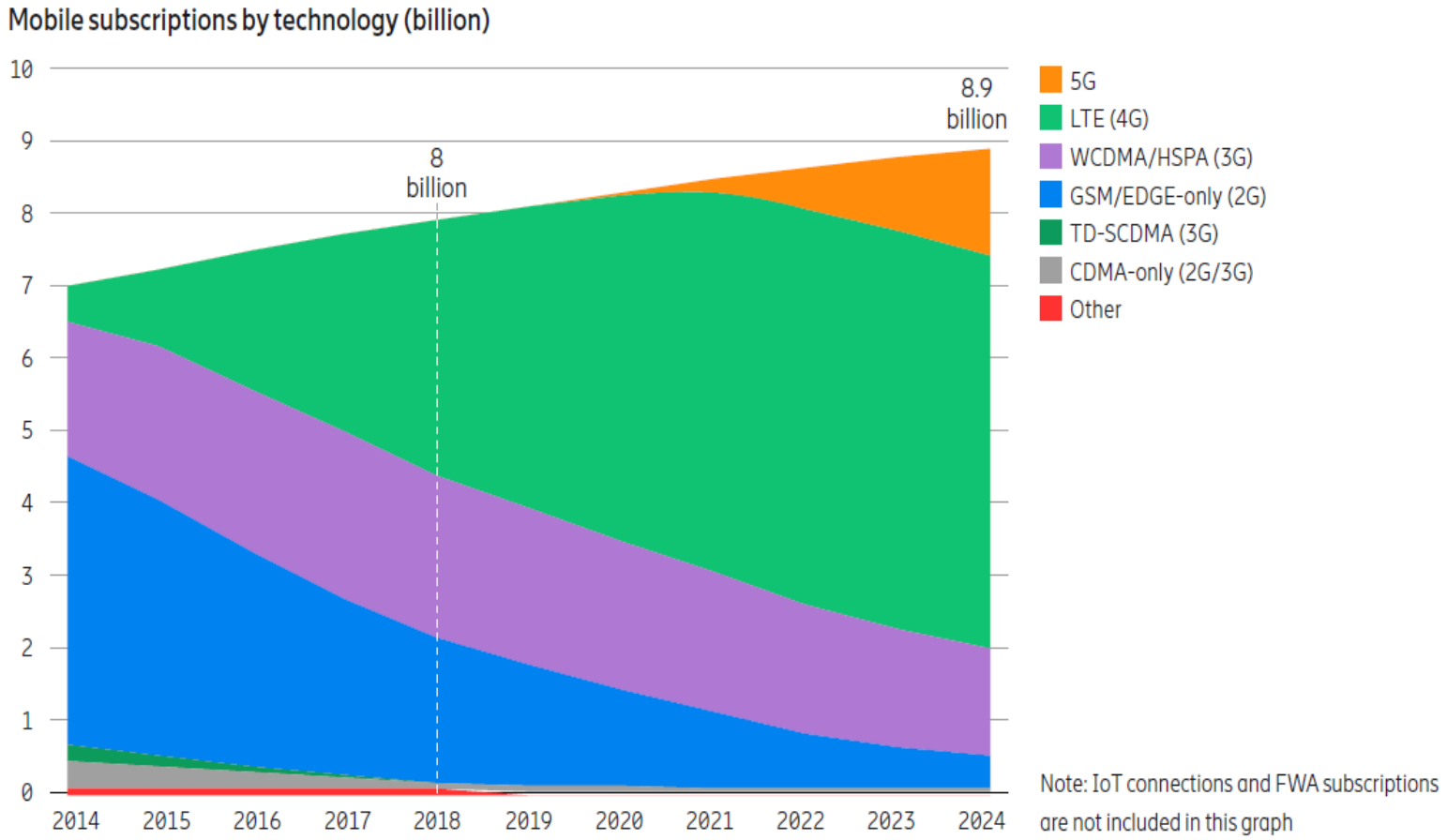

USD bn
2,500
2,000
1,500
1,000
500
0
New addressable 5G-enabled revenues
Current operator service revenues
36%
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026

사업자 측면 수익 예측(2)



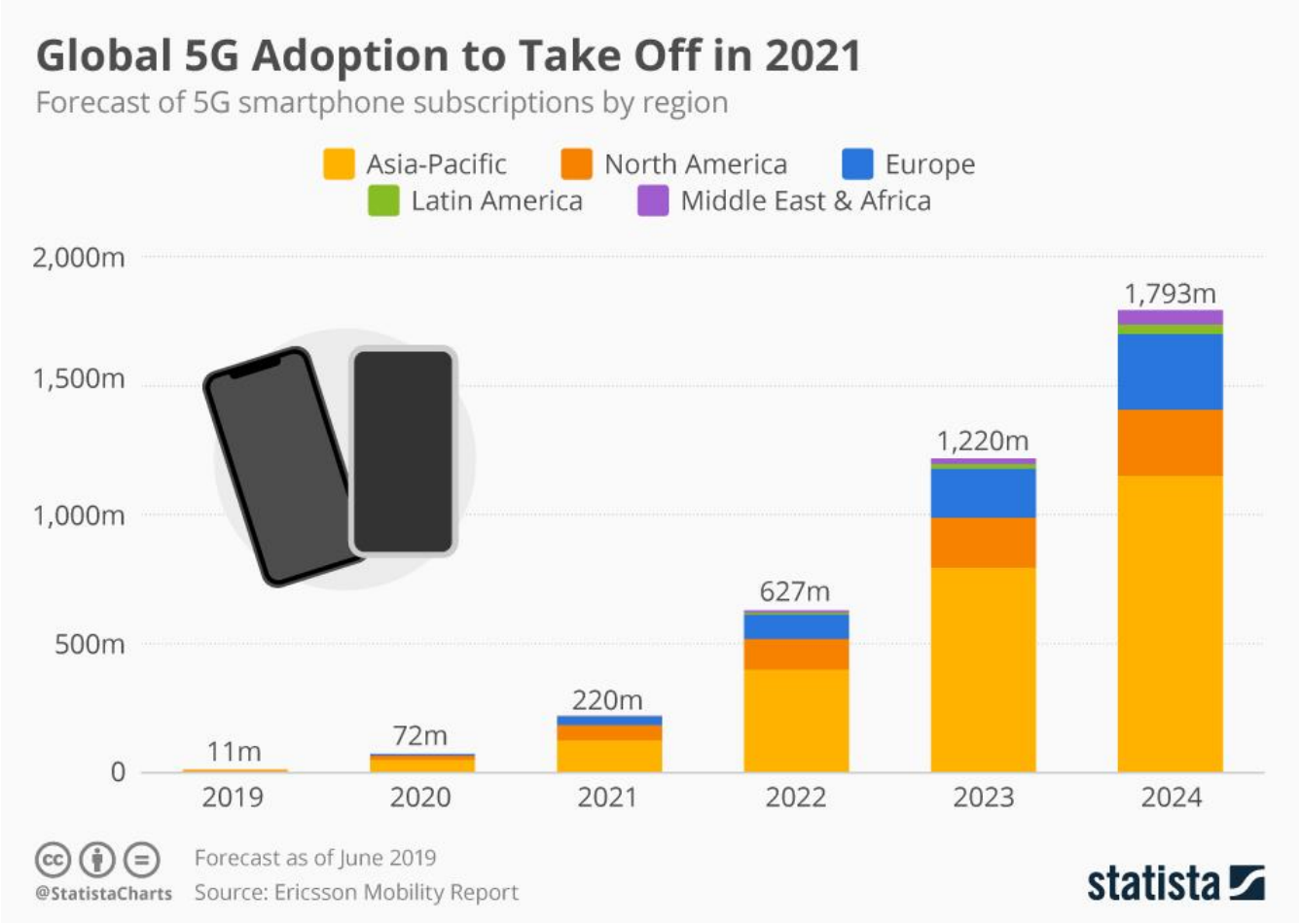
Source: Ericsson and Arthur D. Little

5G 가입자 수 예측(1)



- 5G는 2022년부터 본격화되어 2024년 이후 급증될 것으로 예측
  - 전세계 사업자는 3G➔4G 도입속도보다 4G➔5G 속도가 빠름
- 이유는 모바일 트래픽 급증, 전세계적으로 경쟁 심화

5G 가입자 수 예측(2)


Global 5G Adoption to Take Off in 2021
Forecast of 5G smartphone subscriptions by region
Asia-Pacific
North America
Europe
Latin America
Middle East & Africa
2,000m
1,500m
1,000m
500m
0
11m
72m
220m
627m
1,220m
1,793m
2019
2020
2021
2022
2023
2024
Forecast as of June 2019
@StatistaCharts
Source: Ericsson Mobility Report
statista

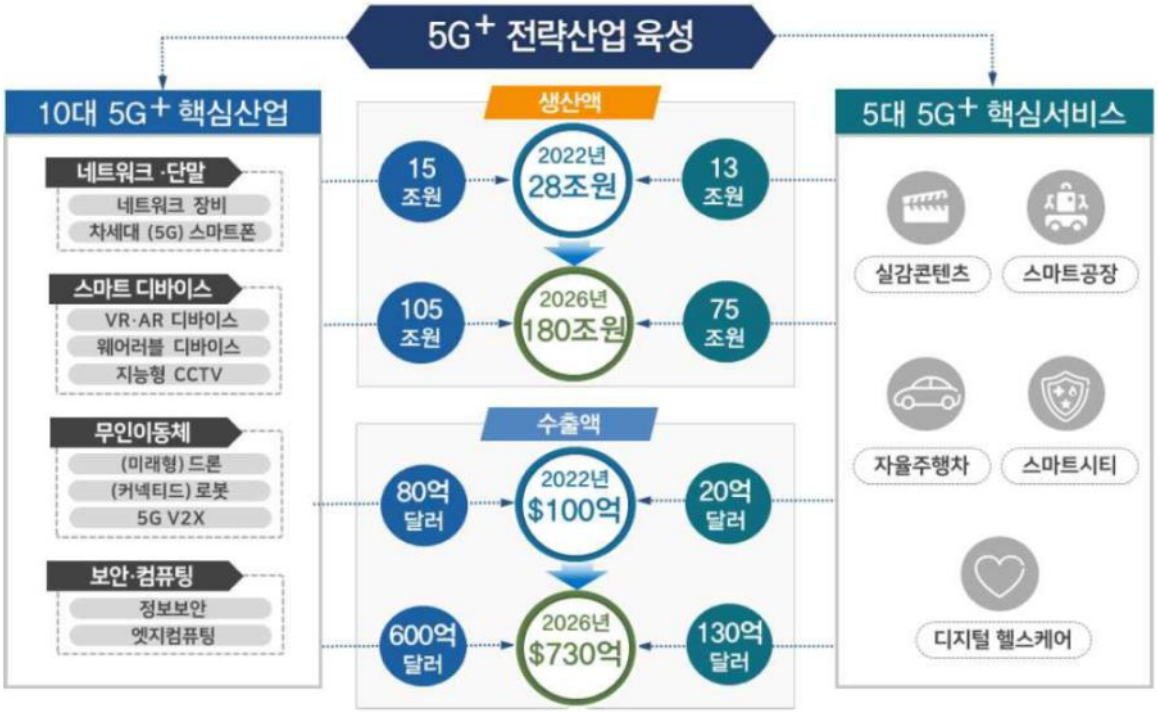
정부정책

세계 최초 5G 상용화를 넘어 5G+로 혁신성장을 실현하겠습니다

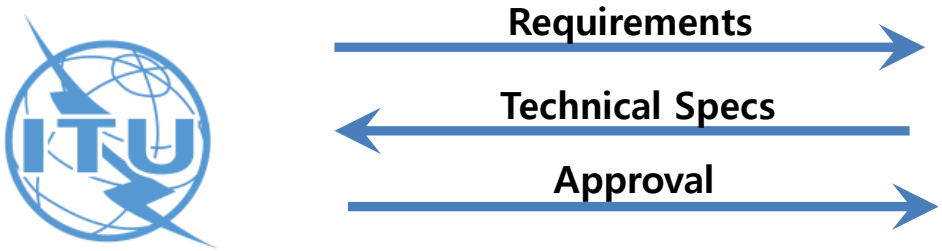
2026년 생산 **180조원**
수출 **730억$**
First Mover형 신산업 창출

2026년까지 **60만 개**
양질의 일자리 창출

국민의 삶의 질 제고
공공서비스 혁신

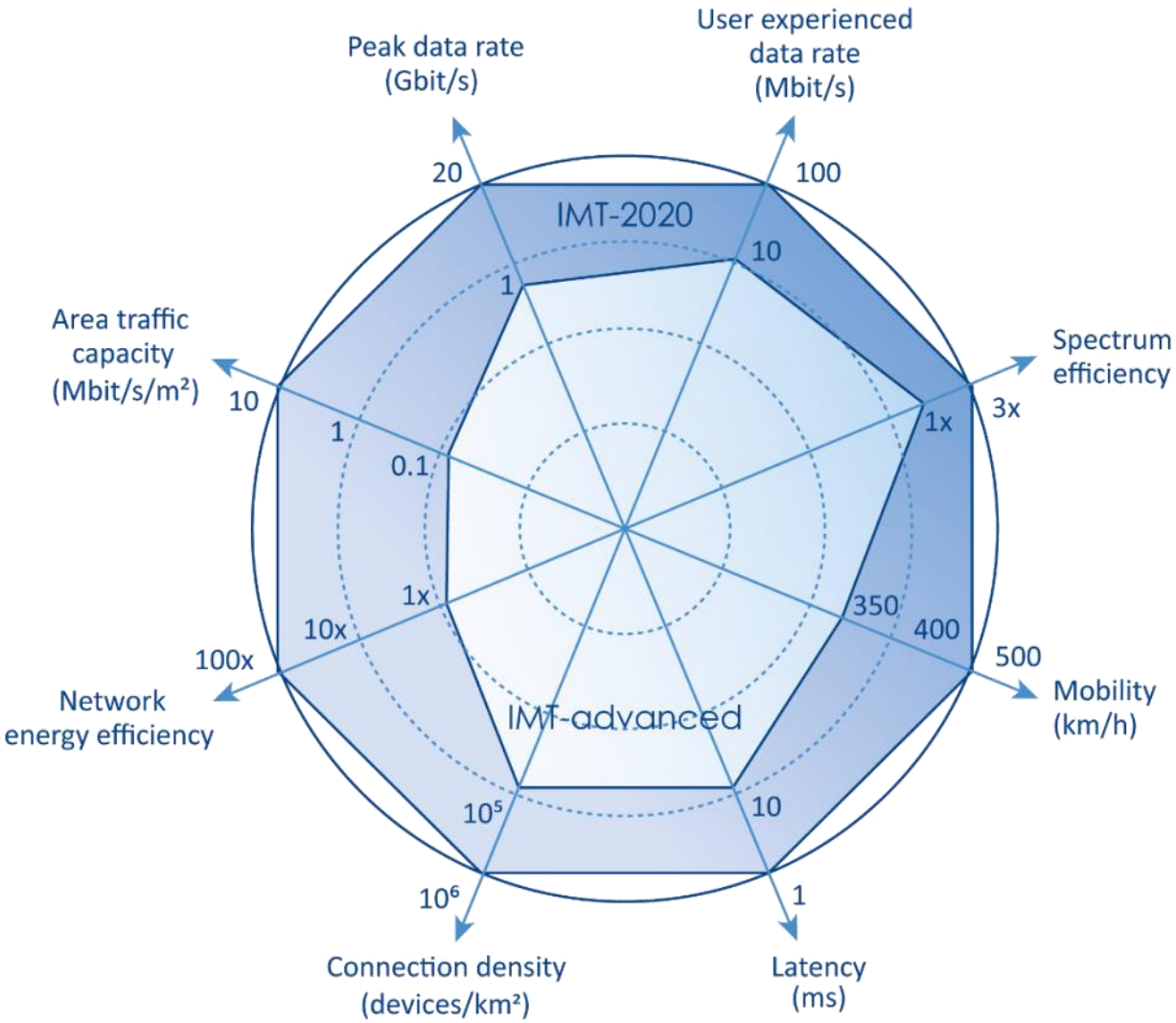


5G 표준화 과정



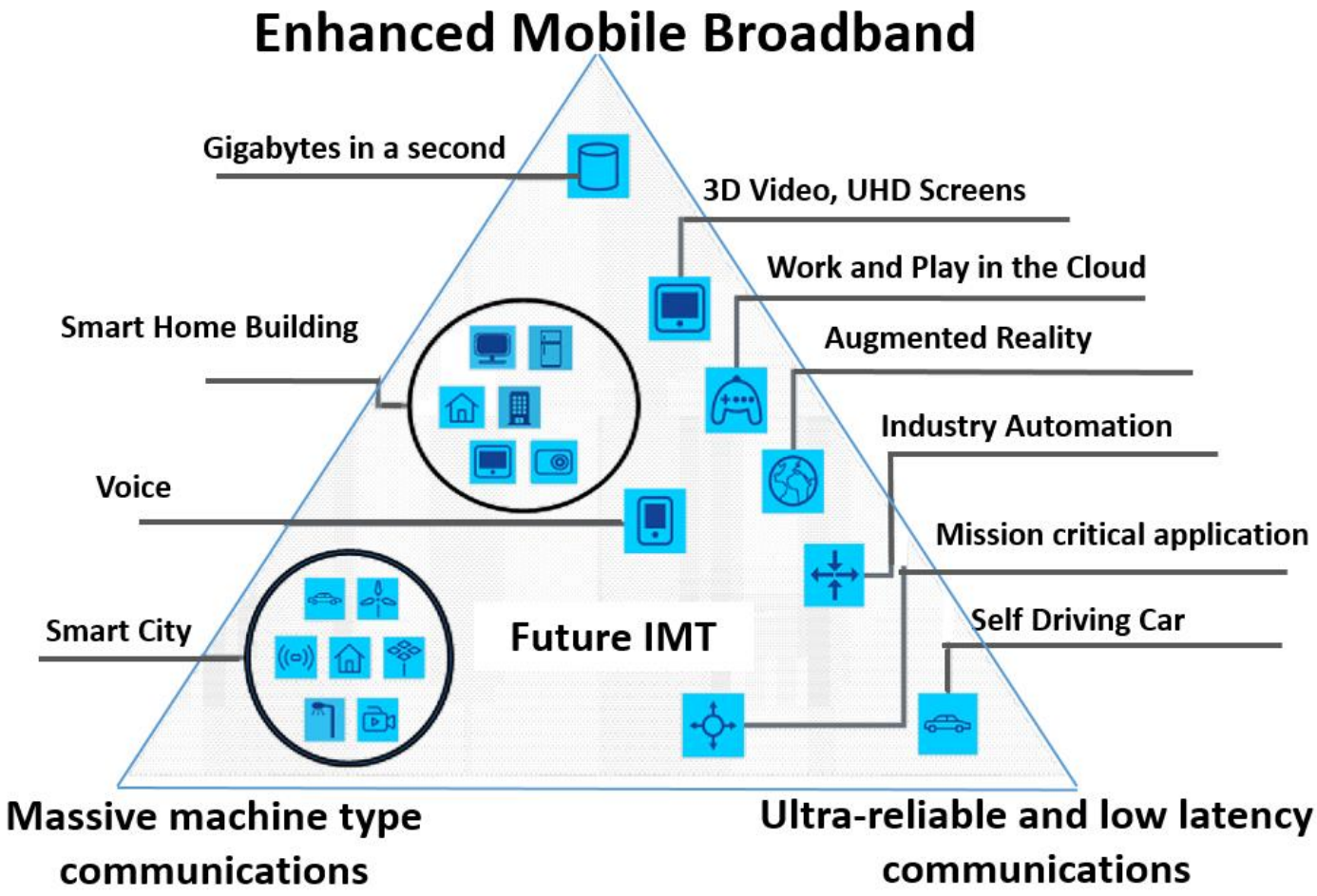
- 5G Spectrum at World Radiocommunication Conferences (WRC) **2015** and **2019**
- Standards Complete **2020**
- Commercial scaled Deployments **2022** onwards

ITU, IMT-2020 요구사항



- ITU는 IMT-2020(5G) 요구사항을 정의하여 3GPP에 전달(2016년)
  - IMT-Advanced(4G) 대비 차이점 위주로 정의
- 5G 요구사항은 크게 전송속도, IoT, Latency로 구분

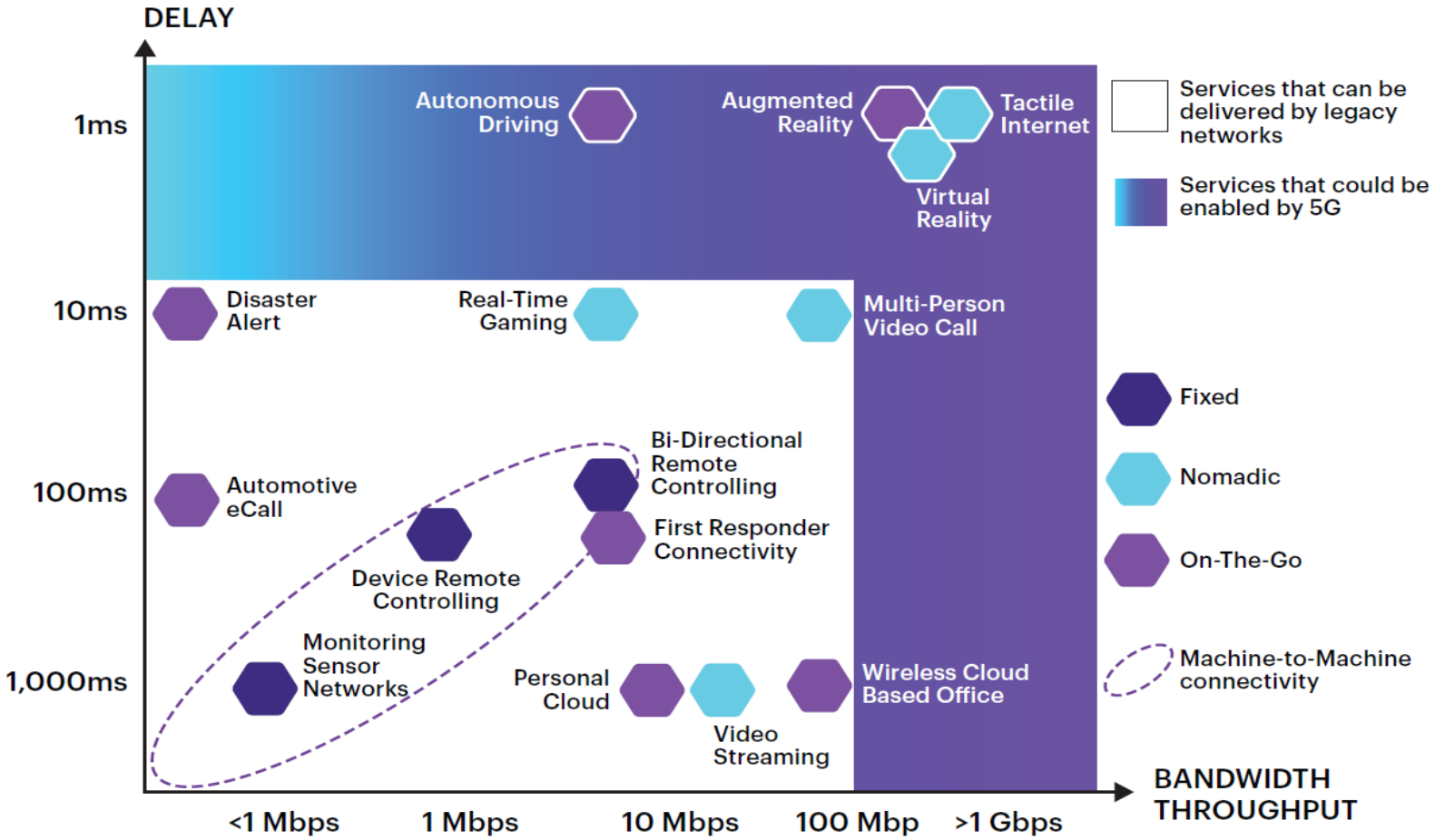
ITU, IMT-2020 주요 서비스



5G 서비스 개요


innovation
The process of translating an idea or invention into a good or service that creates value or for which customers will ...
BD
BusinessDictionary

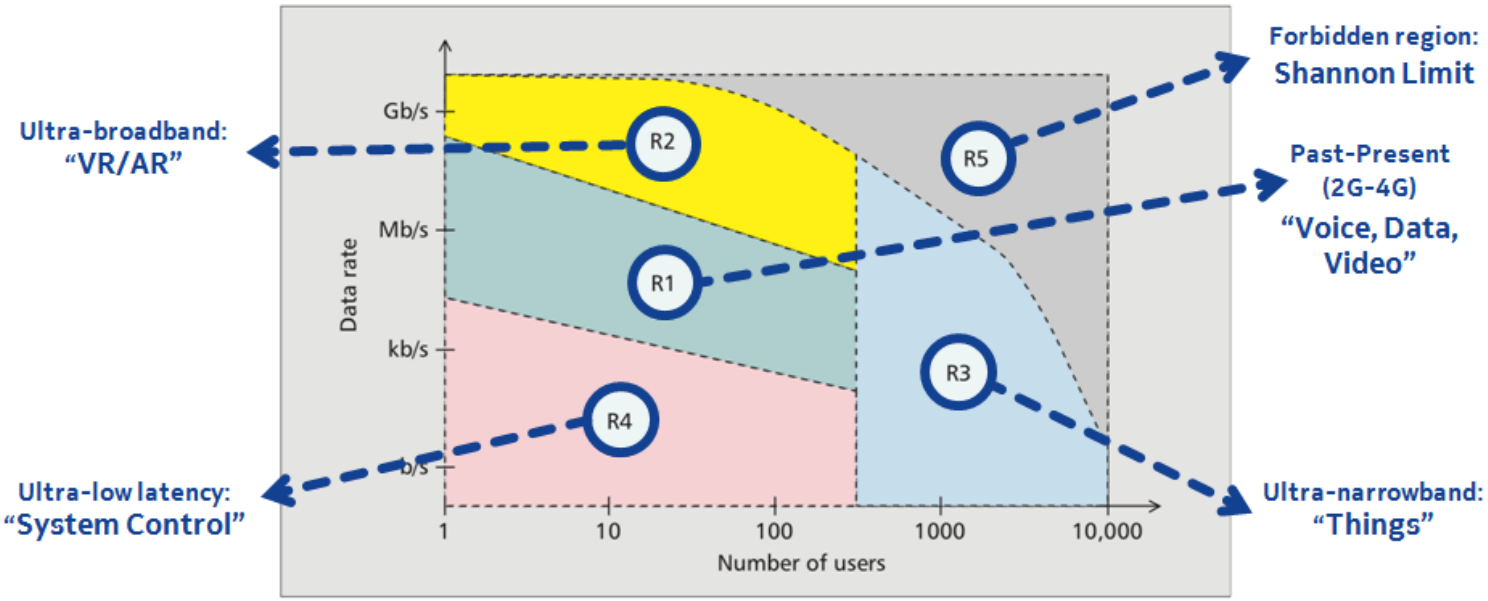
ITU에서 정의한 5G 주요 서비스



- 5G만 가능한 서비스는 자율주행차, AR/VR, Tactile Internet

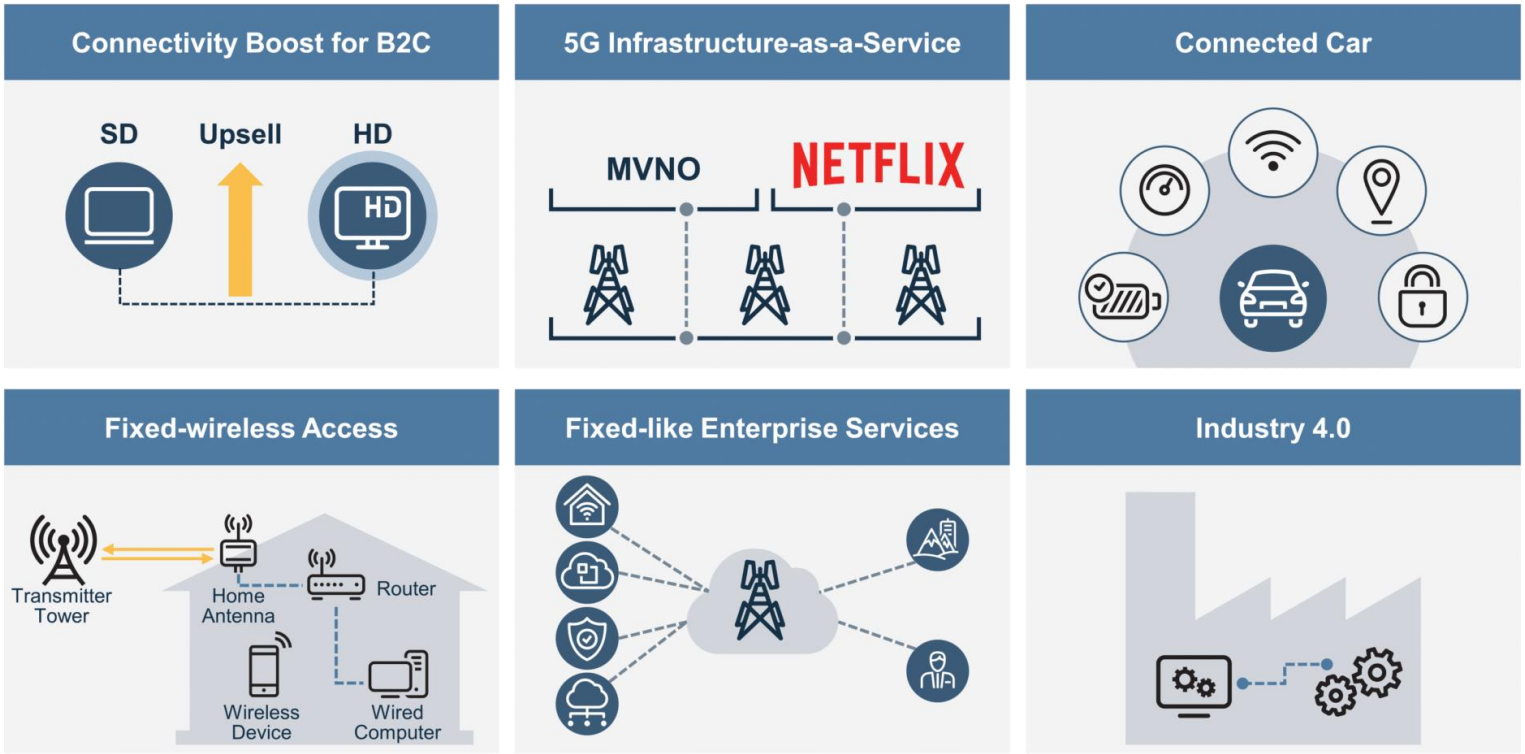
Nomadic: Connectivity is wireless but not ubiquitous - limited to disjoined hotspots

전송속도와 사용자 수로 분류



Source: Bell Labs (Adapted from F. Boccardi, T. Marzetta et al, IEEE Comms. Magazine, 201402)

5G 주요 서비스 예(1) – TM Forum



5G 주요 서비스 예(2) – GSMA

Enhanced mobile broadband

- Gigabytes in a second
- Immersive reality
- eSports
- Live in-venue digital entertainment
- Work and play in the cloud

5G-based fixed wireless

- Last-mile technology for fixed broadband access

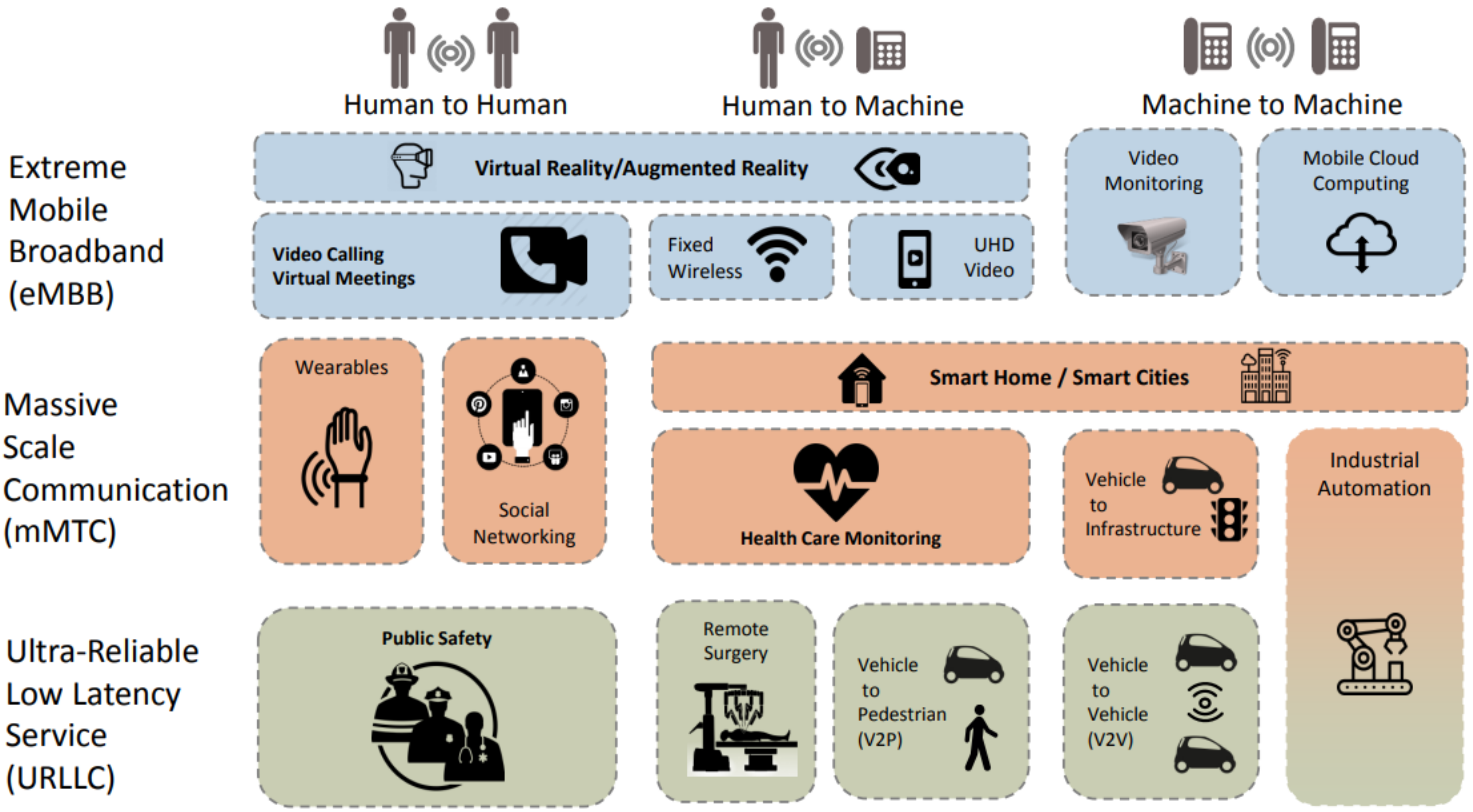
Massive Internet of Things

- Smart homes
- Smart cities
- Smart buildings
- Multiple vertical industries
- Wearables

Ultra-reliable, low-latency communications

- Autonomous driving
- Industrial and vehicular automation
- Robotics
- Remote surgery
- Mission-critical applications

5G 주요 서비스 예(3) – 5G Americas



Enhanced MBB
- 20/10 Gbps DL/UL*
- 4 ms user plane latency
- 500 km/h mobility

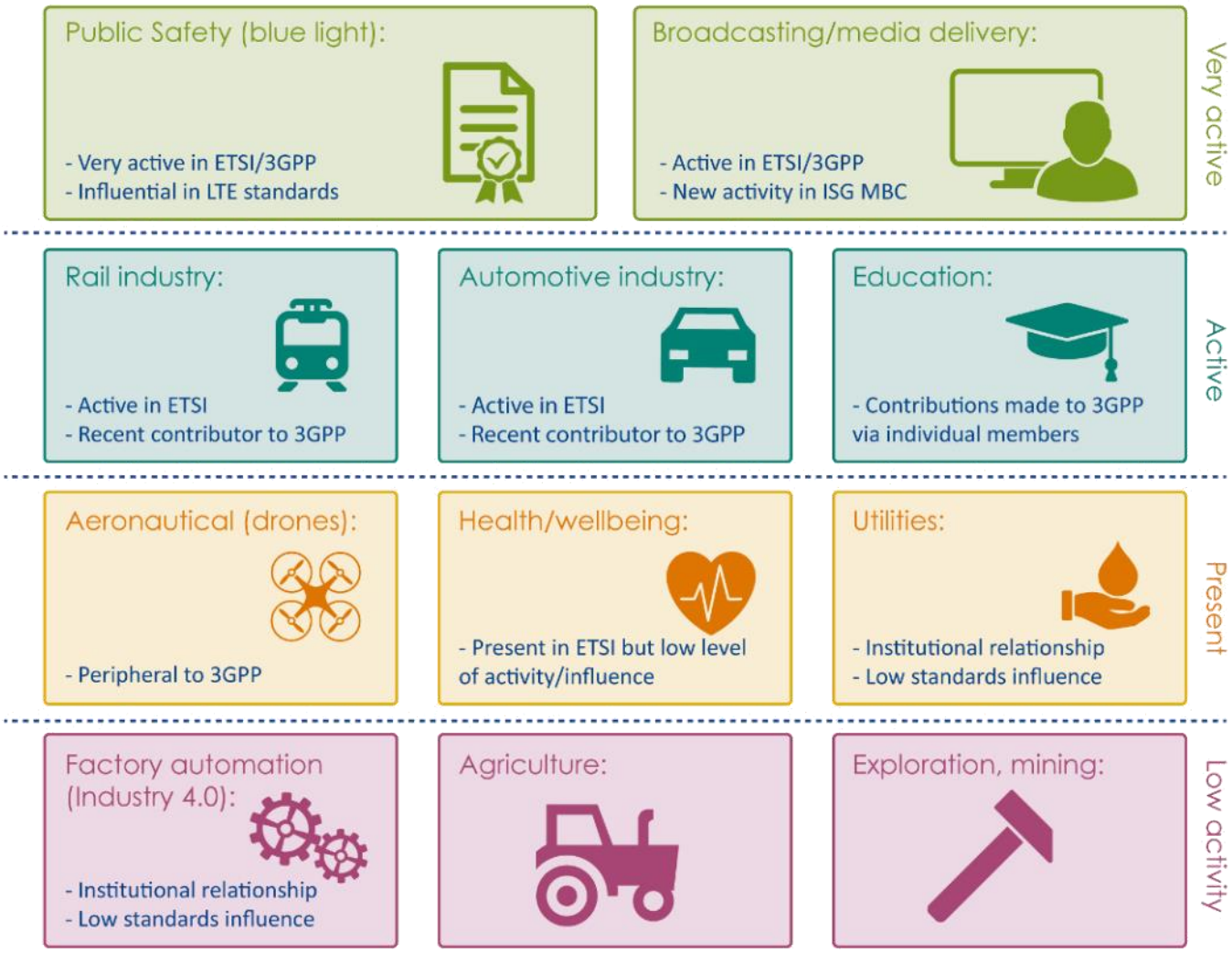
Massive MTC
- 1 million devices / km²
- 10+ years battery life
- 20 dB coverage enhancement

URLLC
- 1 ms user plane latency
- Highly secure / resilient
- 99.99999% availability

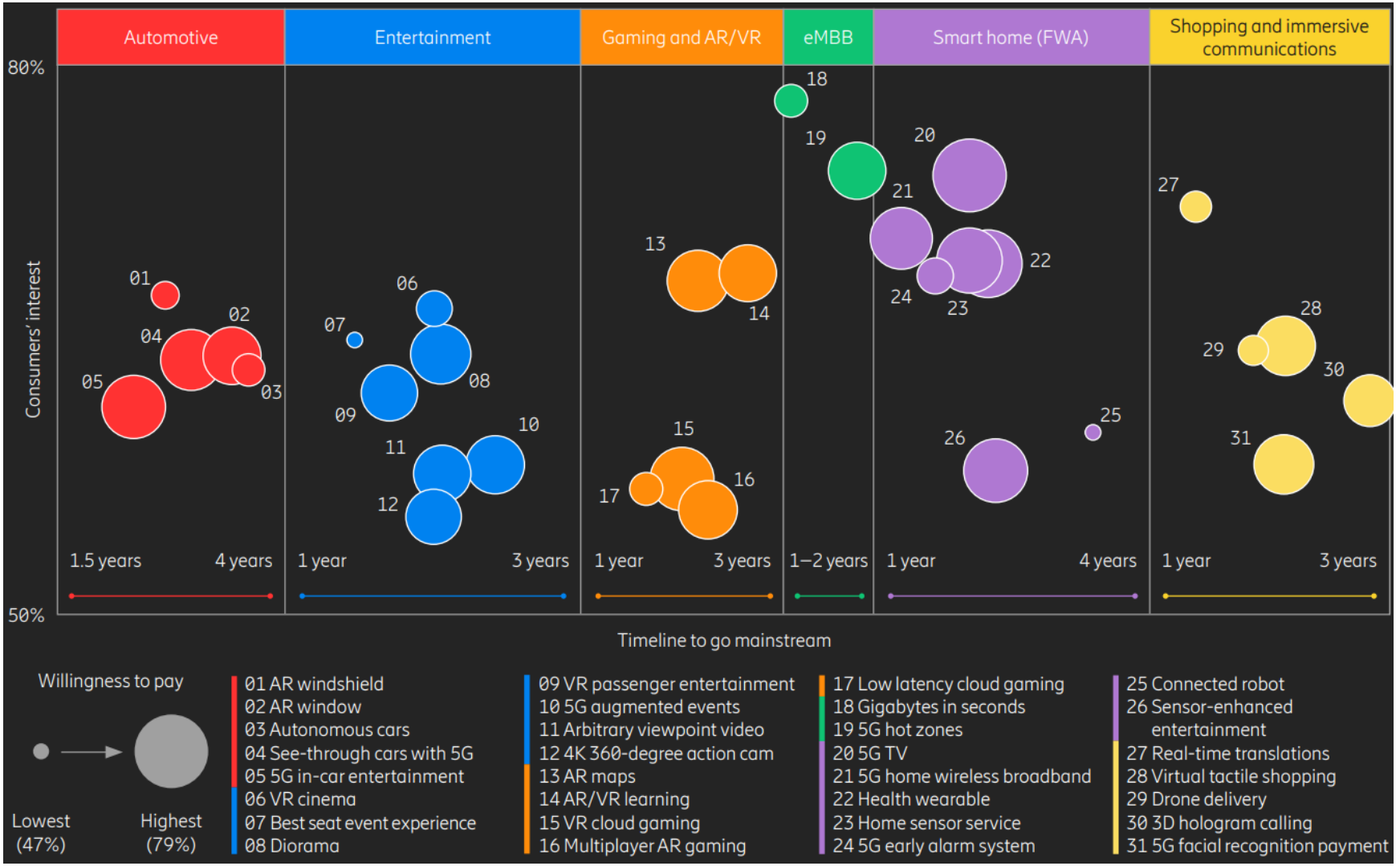
* Peak theoretical rate

Source: 5G Americas

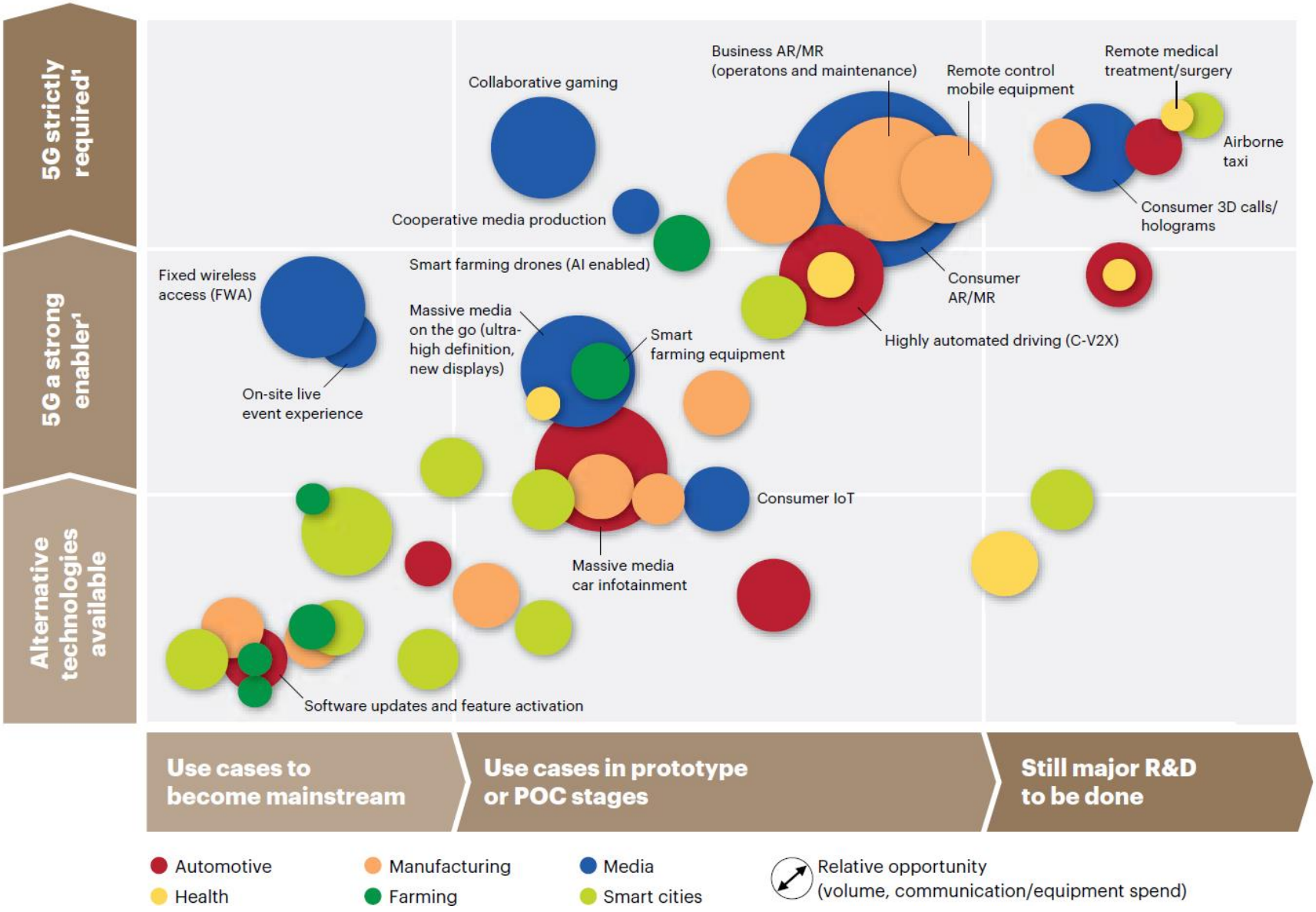
5G 주요 서비스 예(4) - ETSI



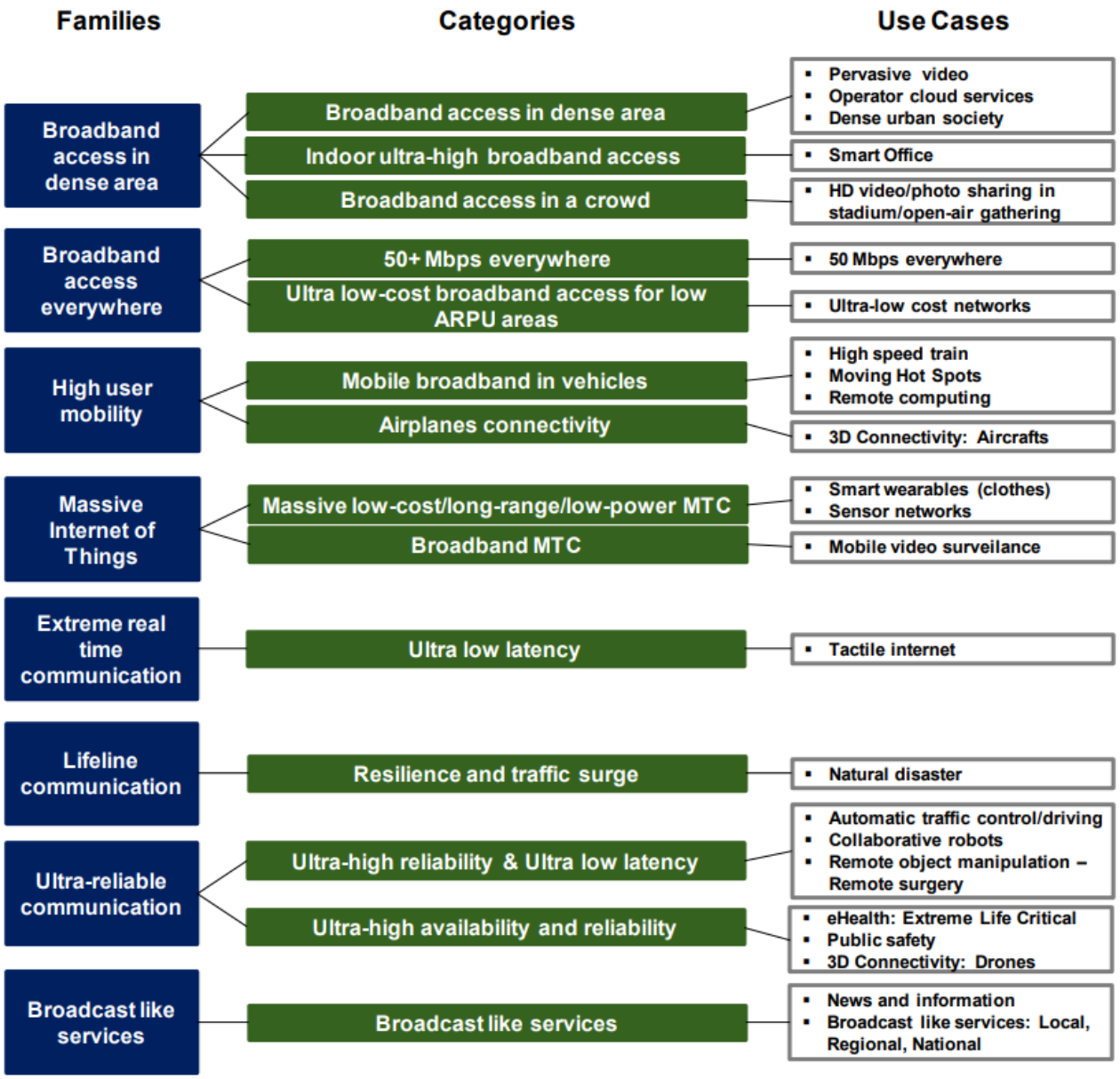
5G 주요 서비스 예(5) - Ericsson



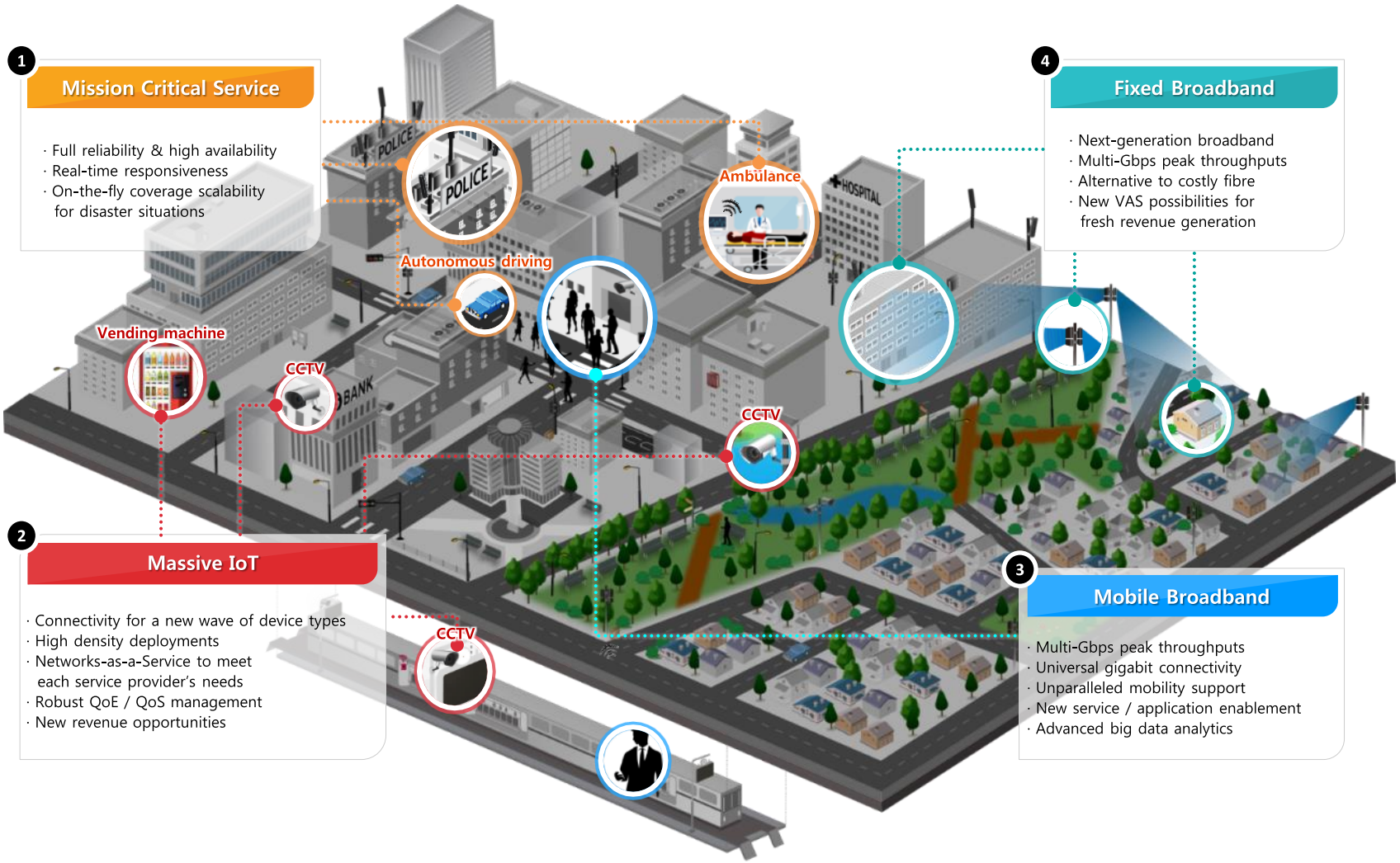
5G 주요 서비스 예(6) – AT Kearney



5G 주요 서비스 예(7) - NGMN



5G 주요 서비스 예(8)

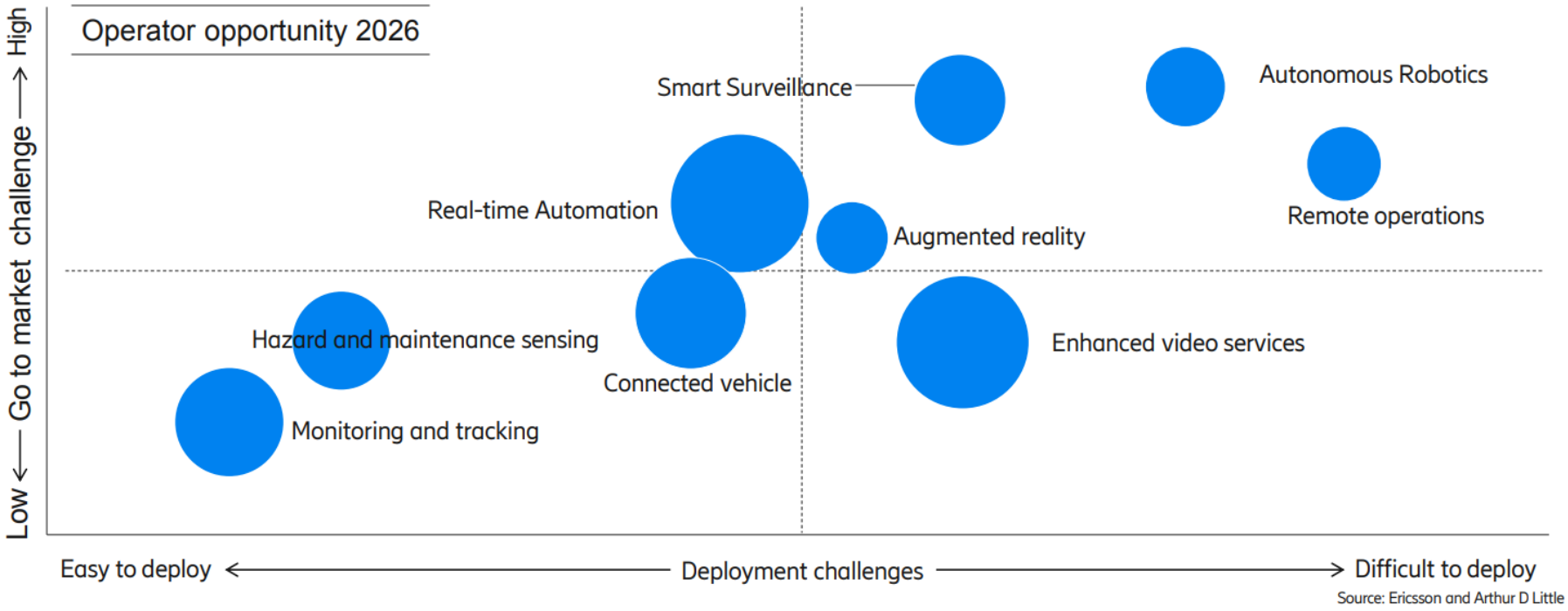

1
Mission Critical Service
· Full reliability & high availability
· Real-time responsiveness
· On-the-fly coverage scalability for disaster situations
POLICE
POLICE
Ambulance
HOSPITAL
Autonomous driving
Vending machine
CCTV
BANK
CCTV
CCTV
4
Fixed Broadband
· Next-generation broadband
· Multi-Gbps peak throughputs
· Alternative to costly fibre
· New VAS possibilities for fresh revenue generation
2
Massive IoT
· Connectivity for a new wave of device types
· High density deployments
· Networks-as-a-Service to meet each service provider's needs
· Robust QoE / QoS management
· New revenue opportunities
3
Mobile Broadband
· Multi-Gbps peak throughputs
· Universal gigabit connectivity
· Unparalleled mobility support
· New service / application enablement
· Advanced big data analytics

5G Vertical Services

정부에서 정의한 5G+ 핵심 서비스

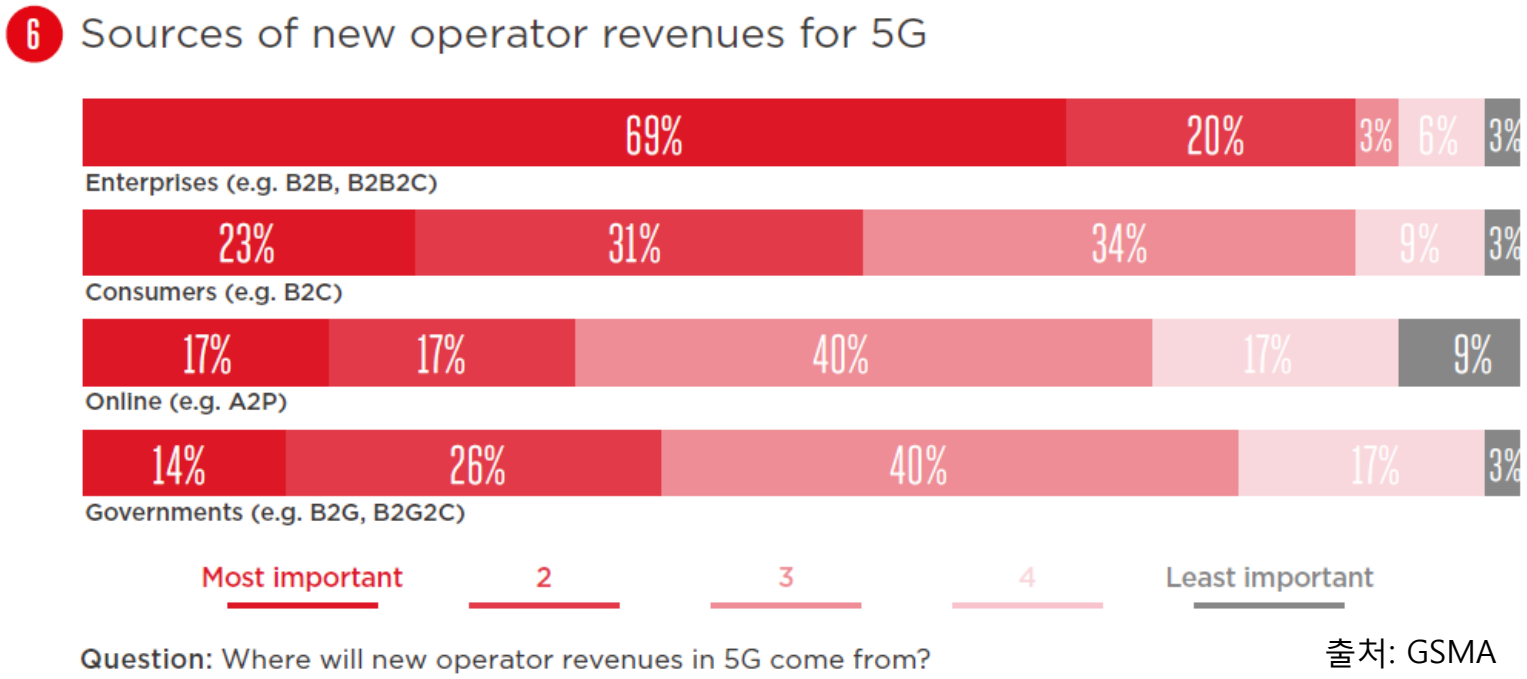
구 분		추진내용
실감콘텐츠		◦ **360° 멀티뷰**(다시점) **e-sports 생중계** 시범사업 추진('19), **5G-디지털사이니지**(K-POP 중계 등) 서비스(상암) 제공*('19) * Digital Media Street에 5G 디지털사이니지·핫스팟존 구축
스마트공장		◦ 5G 기반 **무선 스마트공장용 실시간 품질검사**(머신비전), **물류이송로봇, AR 생산현황 관리** 등 실증(~'20, 시화공단) * '5G 기반 스마트팩토리 얼라이언스'('18.12)를 통해 기술표준화
자율주행차		◦ 5G **자율주행 셔틀**(판교, 대구) 및 교통약자용 **주문형 모빌리티**(대구) **실도로 실증**('20), **인공지능 교차로** 서비스 개발·실증('20)
스마트시티	 	◦ 무선 **CCTV 기반 지능형 도로안전** 지원 서비스 실도로 실증(대전, ~'20), **드론 기반 공공시설물 원격관제** 실증(대구, ~'20) ◦ **화재, 건물붕괴, 대형 교통사고**(터널, 교량 등) 대응 등 국민안전을 위한 5G 재난안전 서비스 실증(강원도, ~'20)
디지털 헬스케어		◦ **응급현장·구급차·병원**을 연결, **중증외상·심근경색** 등의 신속한 처치를 지원하는 **'5G 기반 응급의료시스템'** 개발·적용*('19~'21) * 과기정통부·복지부·소방청 협업으로 개발·실증 추진

구현 난이도별 서비스



Source: Ericsson and Arthur D Little

5G 사업자가 원하는 서비스 형태

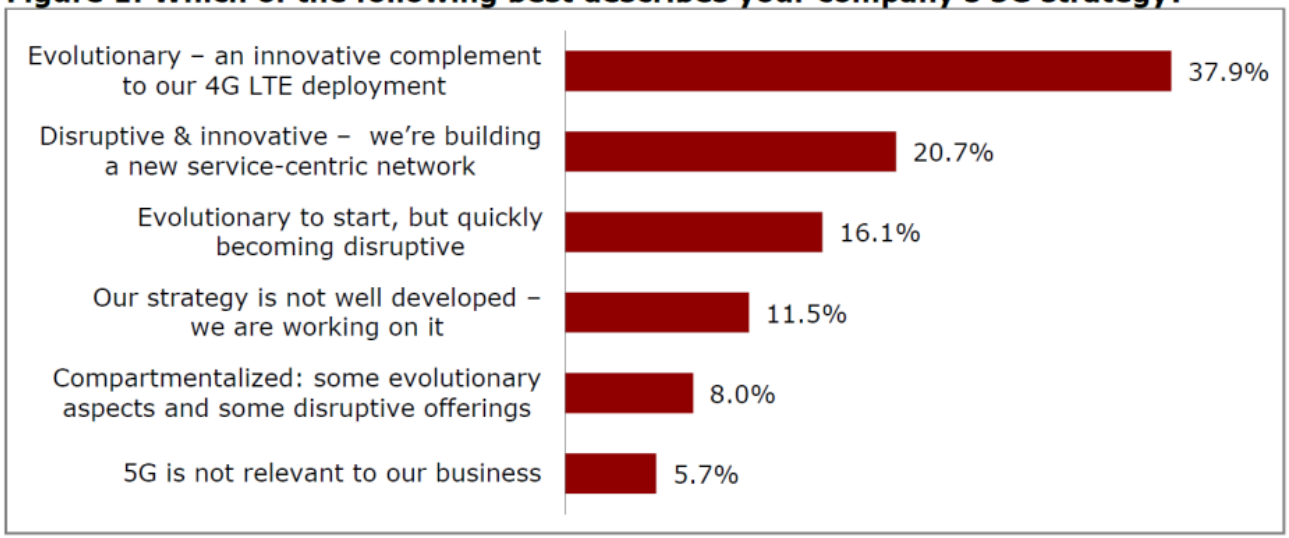


출처: GSMA

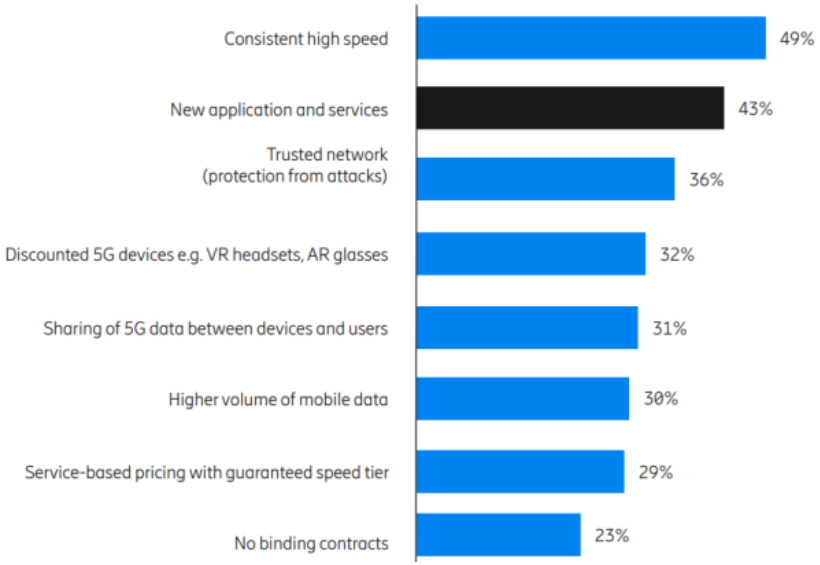
- 대부분 5G 사업자는 B2B 사업에 집중할 예정
  - B2C 시장은 LTE보다 더 좋은 서비스 개발이 어려움
  - 5G망을 SBA(Service Based Architecture)로 개발하여 플랫폼 사업 추구
- 따라서 5G는 IoT와 URLLC를 활용하여 신규 서비스가 개발될 예정

5G 서비스에 대한 인식

Figure 1: Which of the following best describes your company's 5G strategy?



Source: Heavy Reading 5G Survey (n=79)

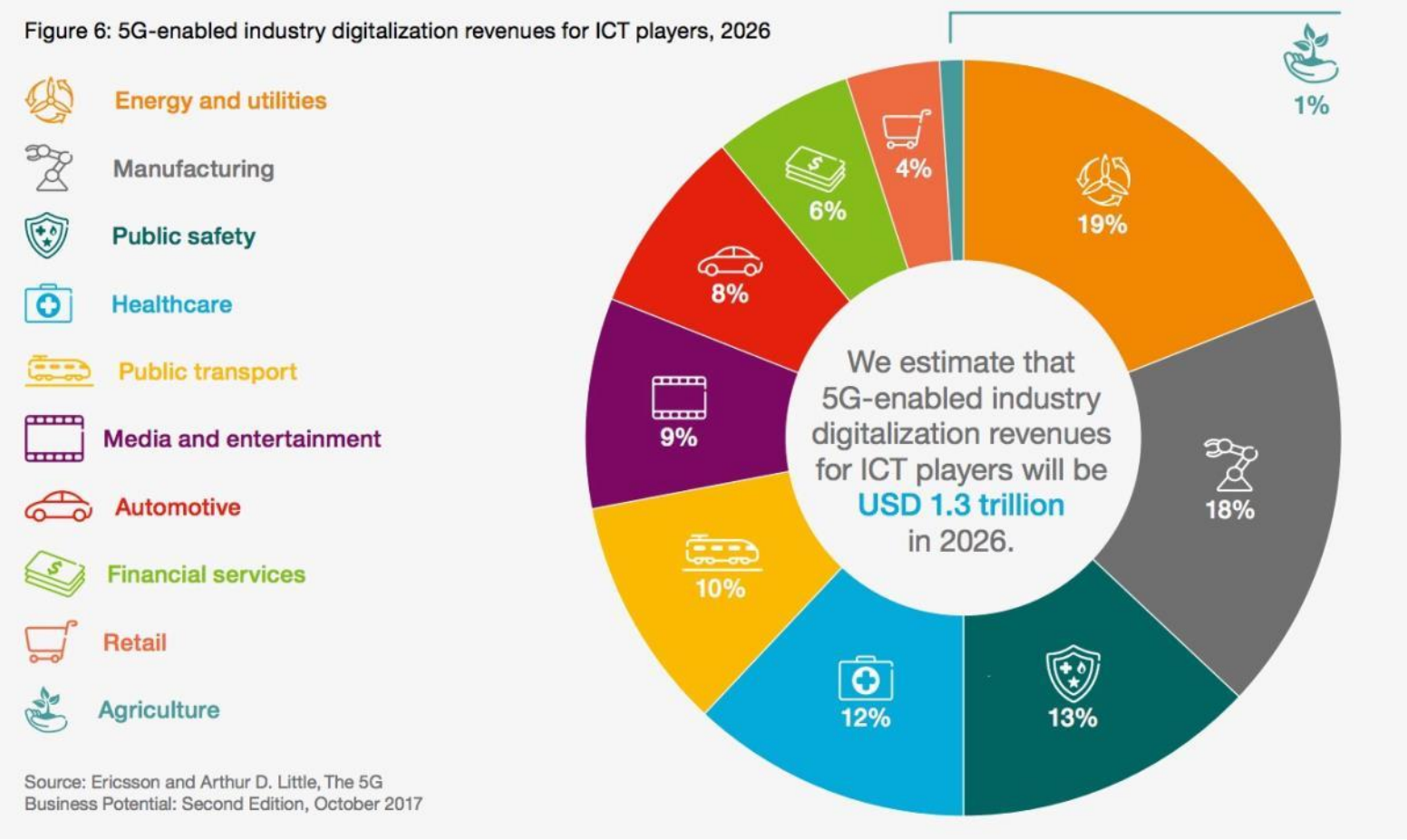


4 in 10

New applications and services are expected as an important part of the 5G plan by 4 in 10 smartphone users who are willing to pay a significant premium for 5G.

출처: Ericsson

5G 관련 산업 매출(1)



- 5G 사업자는 mMTC와 URLLC를 기반으로 Industry 분야에서 사업확대 추진 중
- 매출순위: Energy, Utilities > Manufacturing > Public Safety > Healthcare 등

5G 관련 산업 매출(2)

WHERE THE WIRELESS THINGS ARE AND WHY

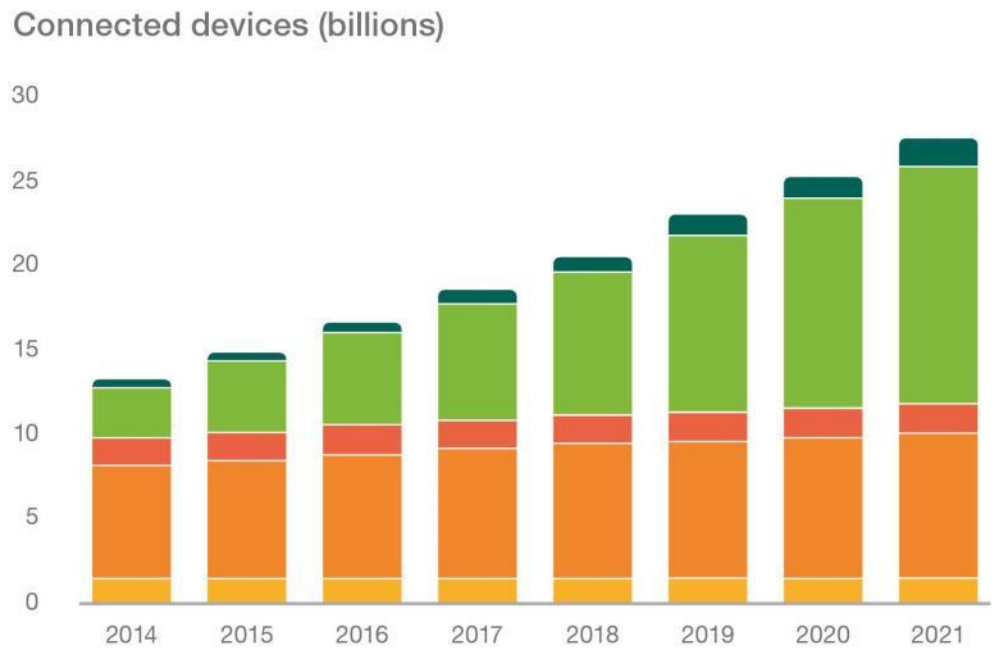
40.2 % Business and Manufacturing
Real-time analytics of supply chains and equipment, robotic machinery.

30.3 % Healthcare Portable
health monitoring, electronic recordkeeping, pharmaceutical safeguards.

8.3 % Retail Inventory tracking
smartphone purchasing, anonymous analytics of consumer choices.

7.7 % Security Biometrics and facial recognition locks, remote sensors.

IoT 디바이스 성장추세

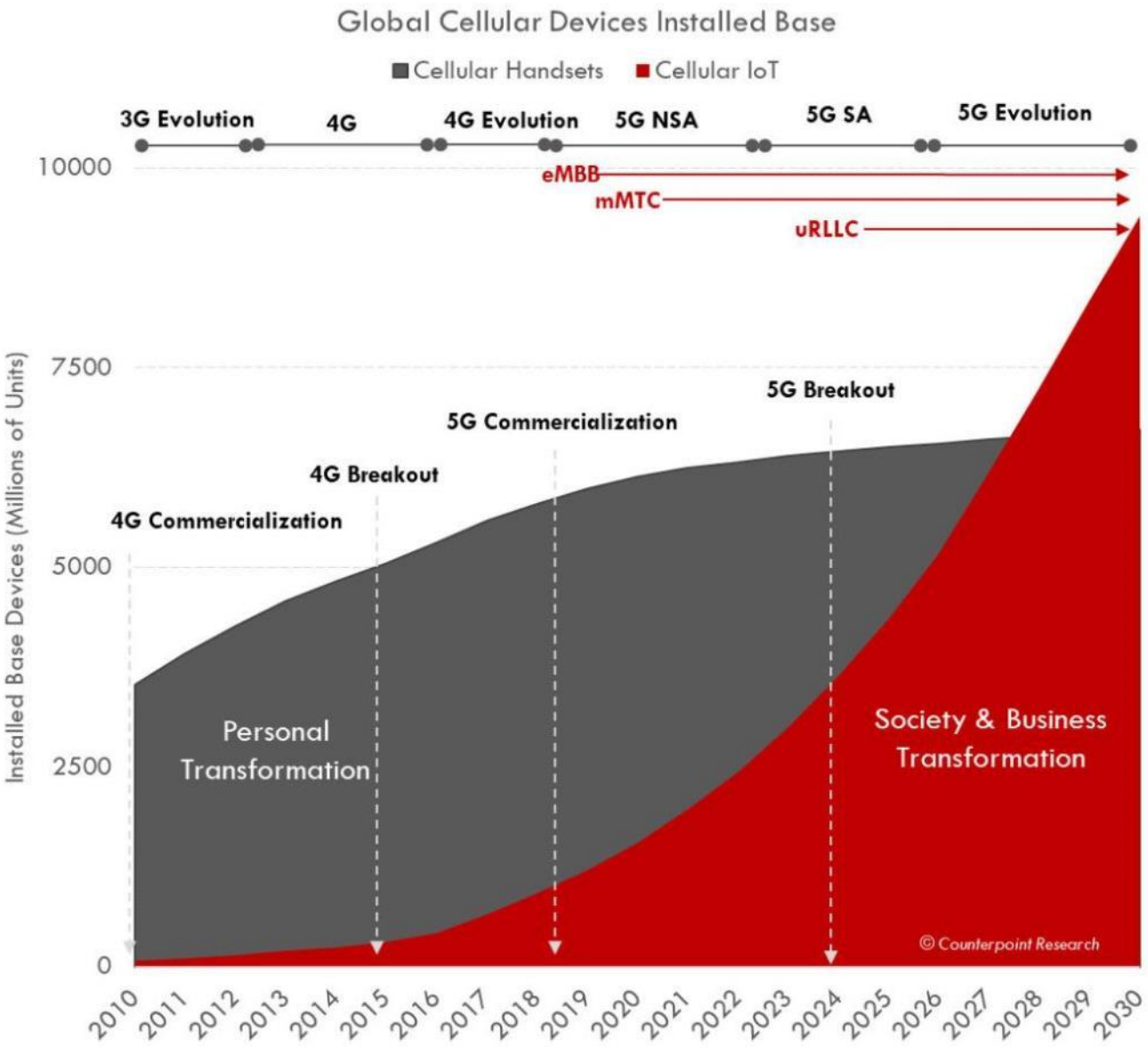


	15 billion	28 billion	CAGR 2015–2021
Cellular IoT	0.4	1.5	27%
Non-cellular IoT	4.2	14.2	22%
PC/laptop/tablet	1.7	1.8	1%
Mobile phones	7.1	8.6	3%
Fixed phones	1.3	1.4	0%

- Connected(항상 인터넷에 연결) Device에서 IoT는 지속적인 성장이 예측됨
  - Mobile Phone은 정체된 상황, 대부분 Connected Device는 IoT

- Wide Area IoT의 성장이 Short Range IoT보다 빠름
  - Wide Area IoT: 셀룰라, LPWA를 활용하는 방식
  - Short Range IoT: 주로 Bluetooth, WiFi를 활용하는 방식

5G 주요 서비스 일정 예측



5G 서비스 사례

미국, 5G 서비스 현황

Timeframe for Deployment	- Plan to rollout to 30 cities by the end of 2019; launched Minneapolis, Chicago in April 19 - Has not announced time frame for nationwide rollout	-Launched 5G in portions of 19 cities most recently Austin, LA, Nashville, Orlando, San Diego, San Fran, and San Jose in April 19 - Nationwide rollout by early 2020	-Announced New York, LA, Dallas and Las Vegas will be among first four cities for 5G launch. Soft launch planned for 1st half of 2019 with broader launch later in 2019	-Plans to launch 5G services in May to Atlanta, Chicago, Dallas, and Kansas City followed by Houston, Los Angeles, New York, Phoenix, and Washington, DC
Service Details	- $10 per month for unlimited data in select markets - Hardware: Mod accessory turns Moto Z3 into a 5G compatible phone	-Netgear Nighthawk 5G mobile WiFi hotspot is only AT&T 5G device available today - Samsung's new Galaxy S10 5G will be available in Spring	- Samsung's new Galaxy S10 5G will be available in Spring 2019 - Additional devices that support T-Mo's low band 600 MHz spectrum will be available later in 2019	-Company tests have indicated speeds 10x current LTE speeds (up to 430 Mbps) - Service will be rolled out out on LG's new V50 ThinQ 5G
Spectrum	- 28 GHz band - utilize licenses acquired in XO/Straight Path acquisitions	-Multiple Bands: sub-6 Ghz range from 700 MHz up to 2300 MHz or 2.3 GHz; eventually may utitlize CBRS at 3.5 GHz	- Primary: Plans to use 600 MHz for nationwide coverage - 28GHz and 39GHz spectrum in urban areas	-Mid-band 2.5 GHz EBS and BRS spectrum. T-Mobile also looks to leverage this spectrum for 5G as part of the Sprint-TMO merger

Verizon, B2C/B2B Services

Verizon, 5G Home(FWA)

How 5G Home works.

Easy to use Wi-Fi gets a boost with totally new technology.

Learn more

Wireless Node

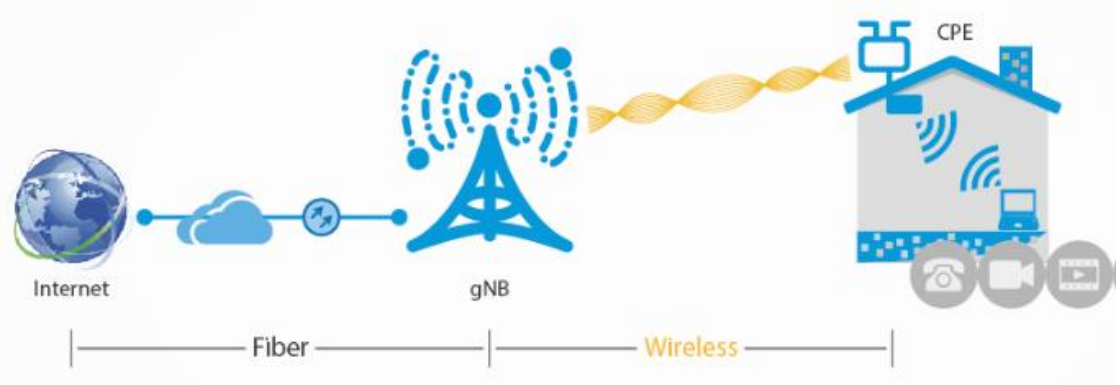
A cell site in your neighborhood creates a 5G signal, which is transmitted wirelessly to your home.

Receiver

This receives the 5G signal, and relays it to a router inside your home. It's usually placed on or near a window.

Router

This creates a Wi-Fi network from the 5G signal. It's powered by 5G wirelessly, instead of with cables. If needed, we'll add free Wi-Fi extenders for extra coverage.



* FWA: Fixed Wireless Access

AT&T, 초고속 통신 기반 서비스

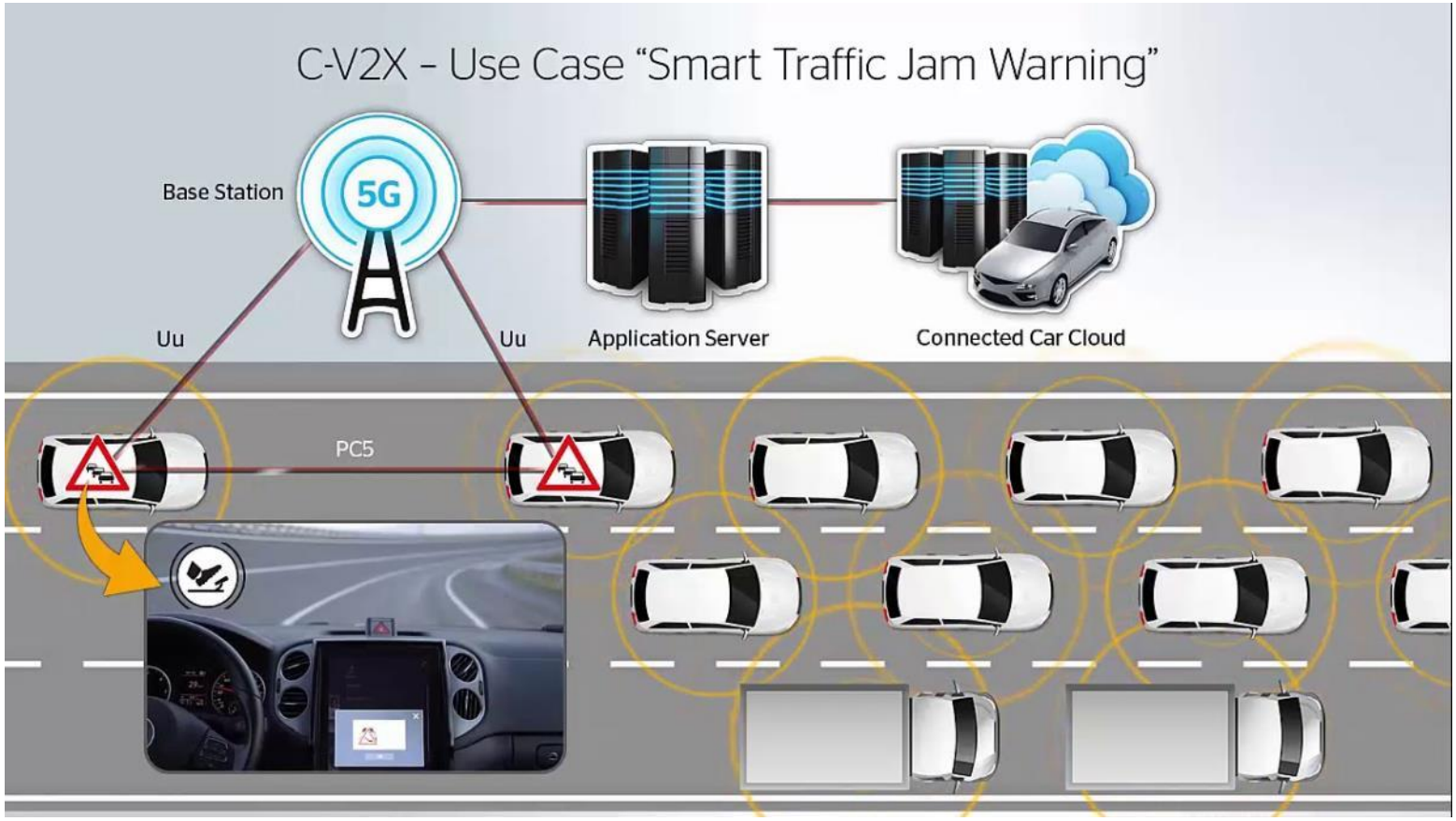
By 2022, we estimate video might make up more than 75% of AT&T's mobile traffic. Adoption of Ultra High Definition (UHD) 4K video, autonomous vehicles, drones, mobile gaming, virtual reality (VR) and augmented reality (AR), will all drive future video traffic.

Bringing 5G-Enabled Robots to Retail

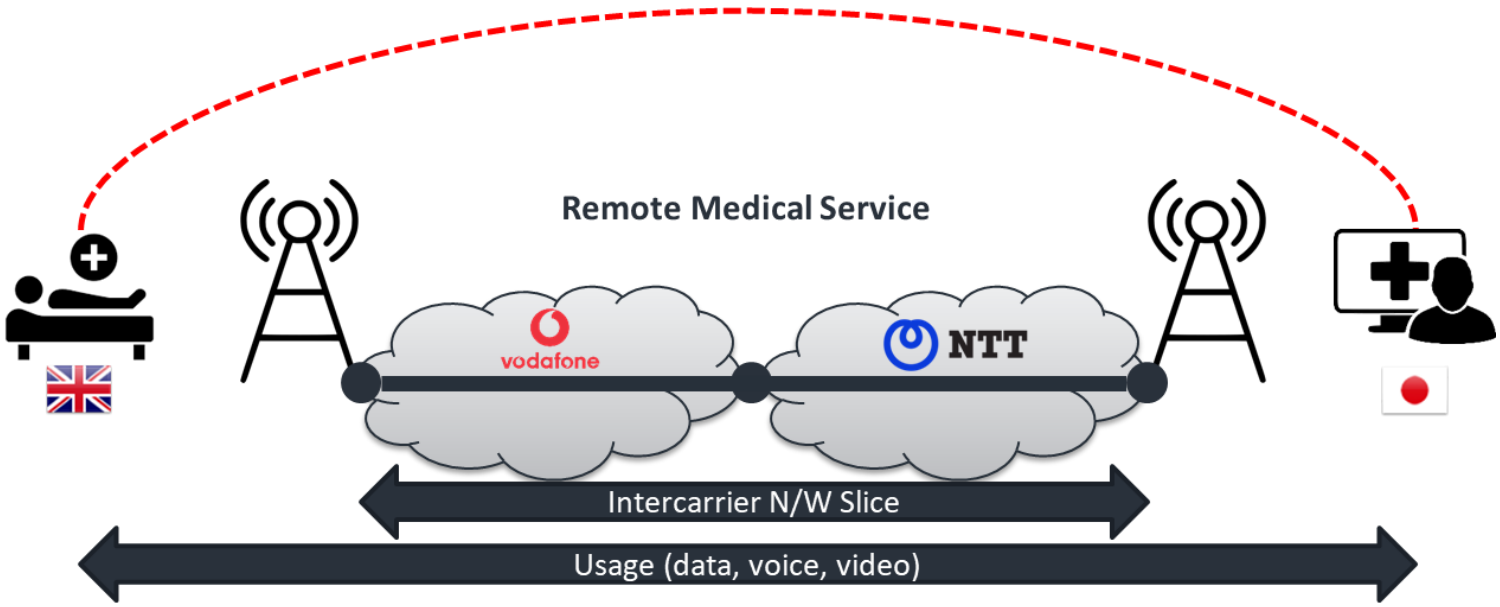
Vodafone, 5G Haptic Tackle

Vodafone/LG U+, 5G Cloud Gaming

Vodafone, Smart Traffic

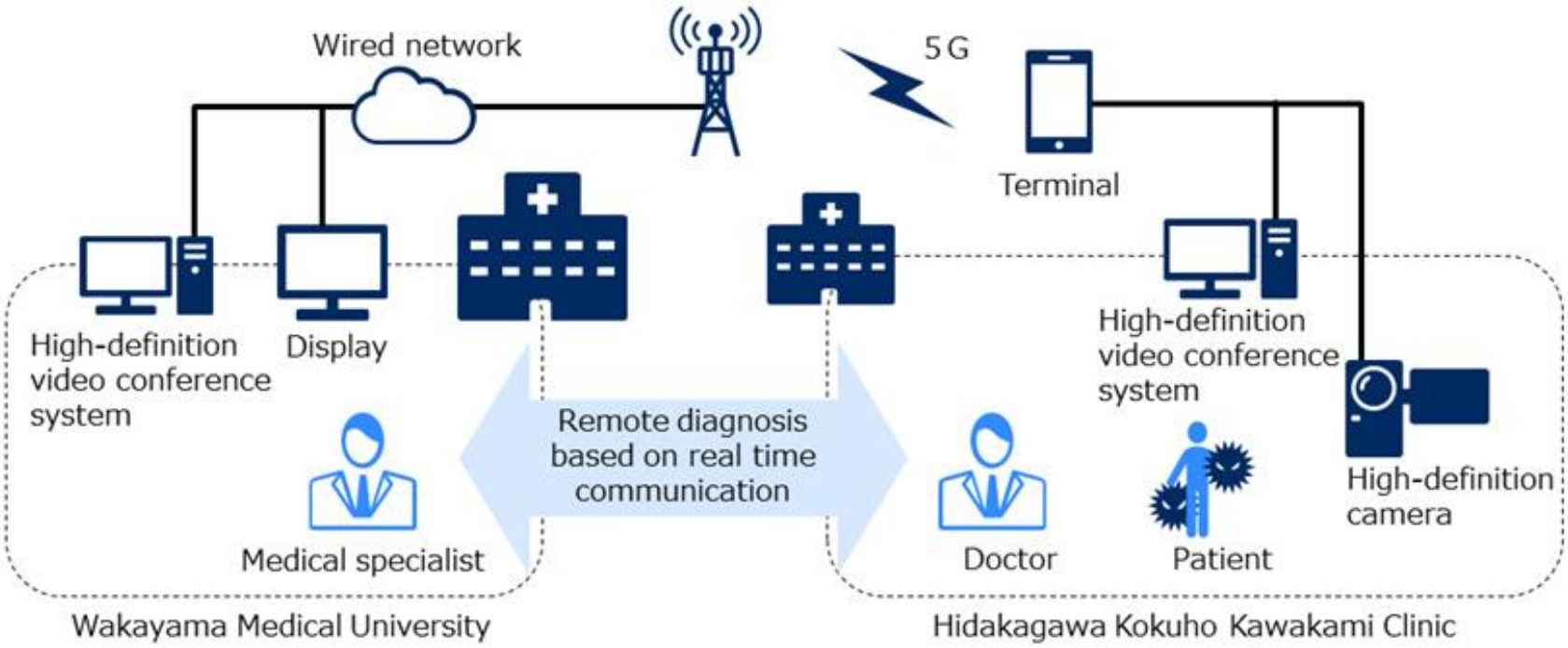


Vodafone - NTT, URLLC 응용

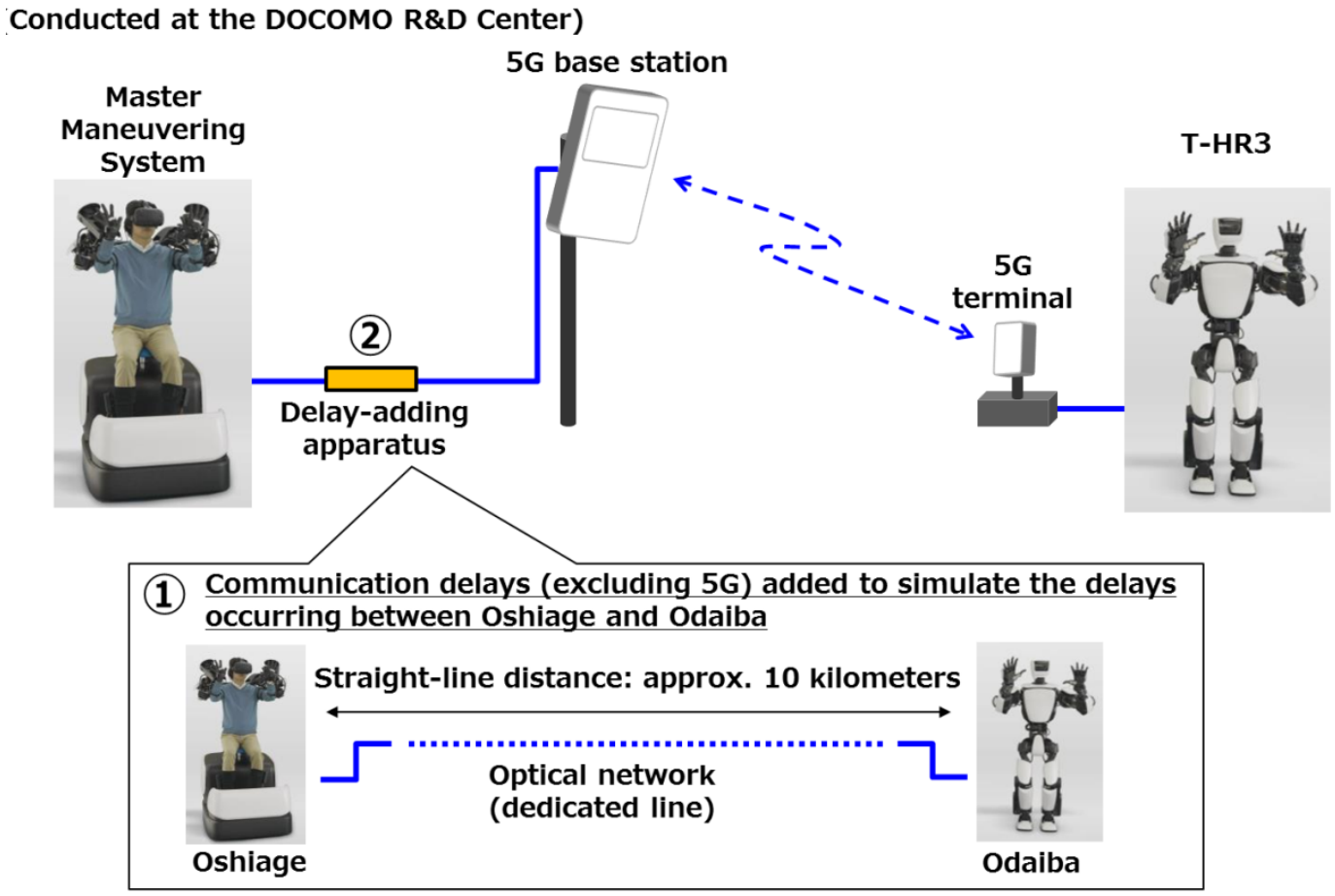


* URLLC: Ultra Reliable Low Latency Communication

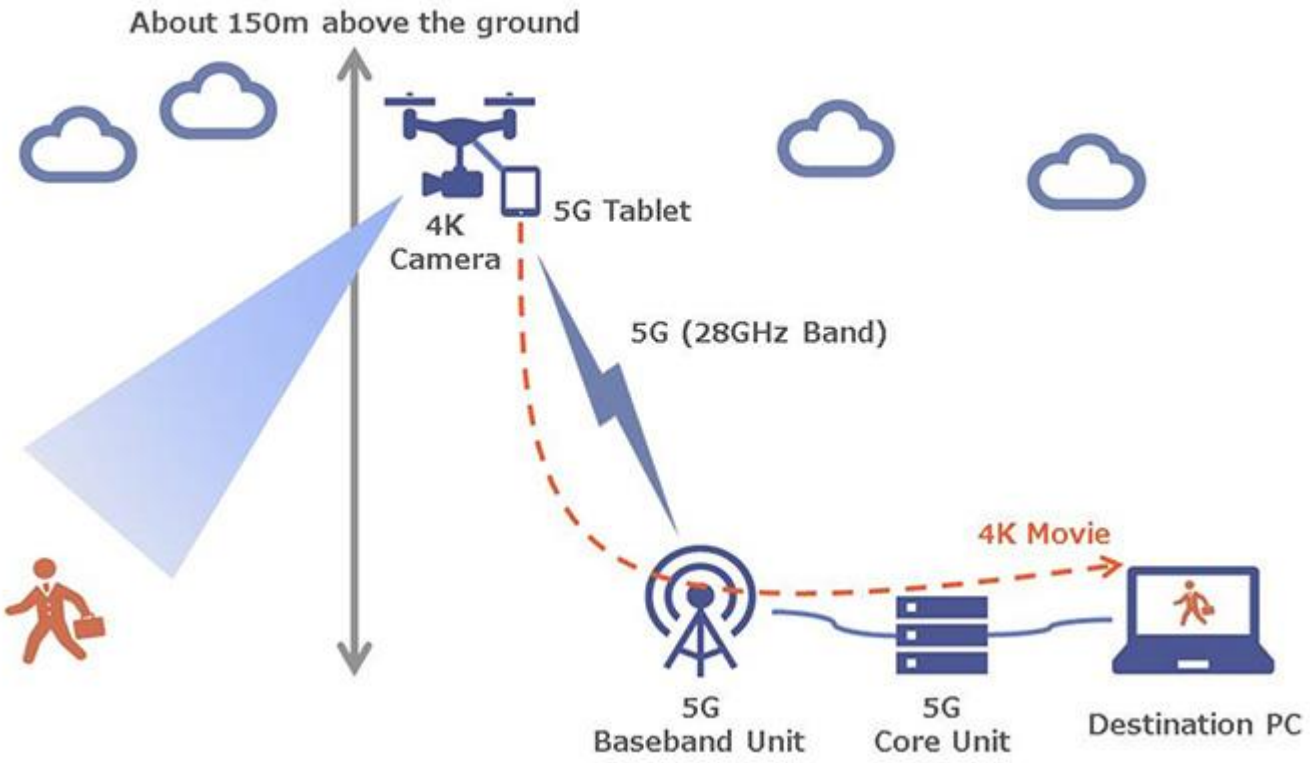
NTT docomo(NEC 장비 사용), 원격치료



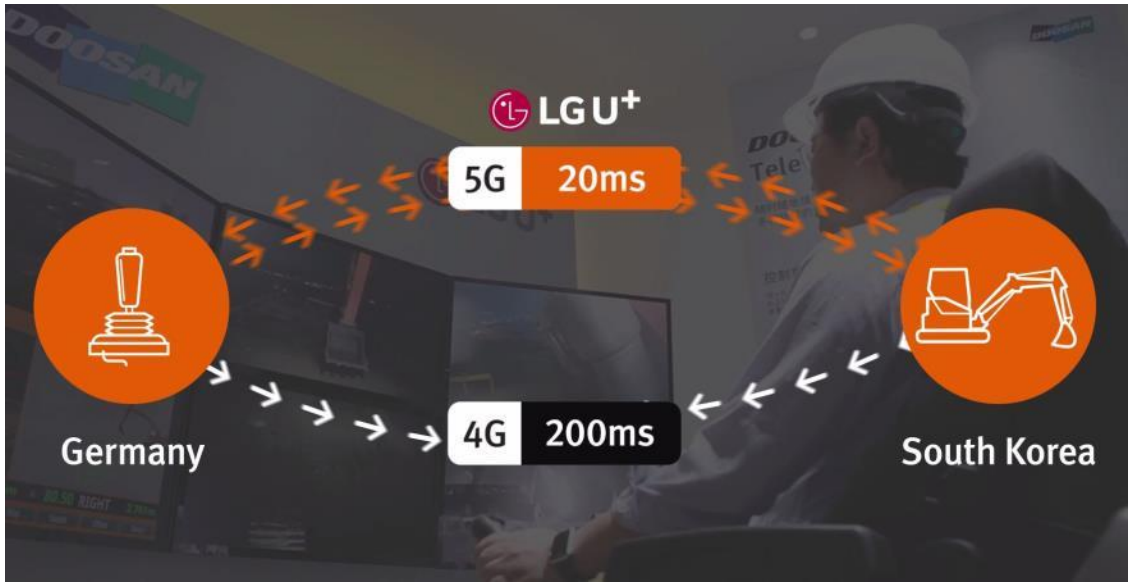
NTT docomo, 실시간 로봇제어

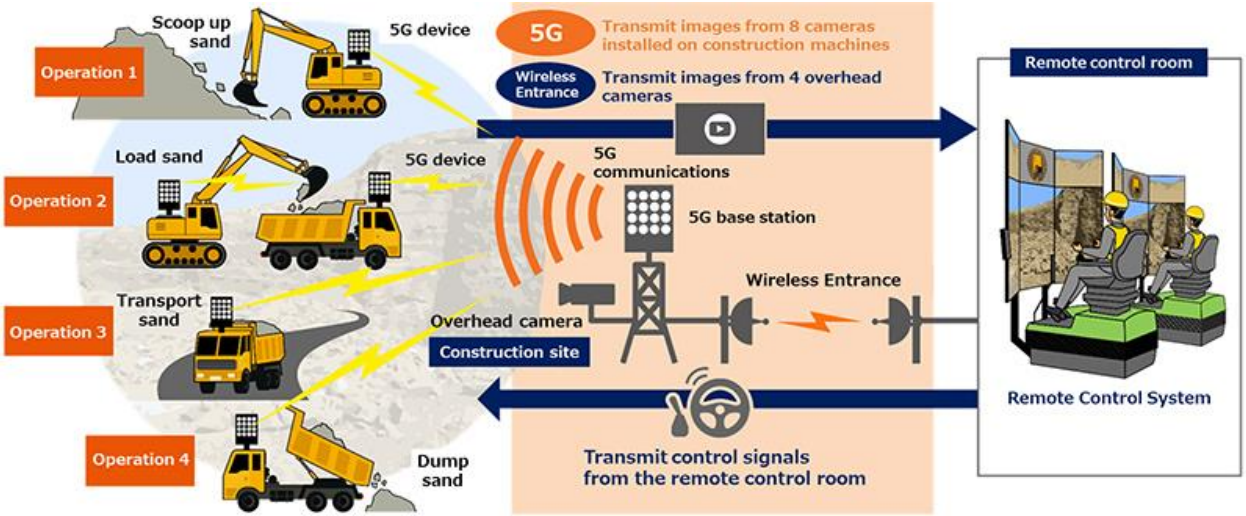


KDDI, Drone 4K Video

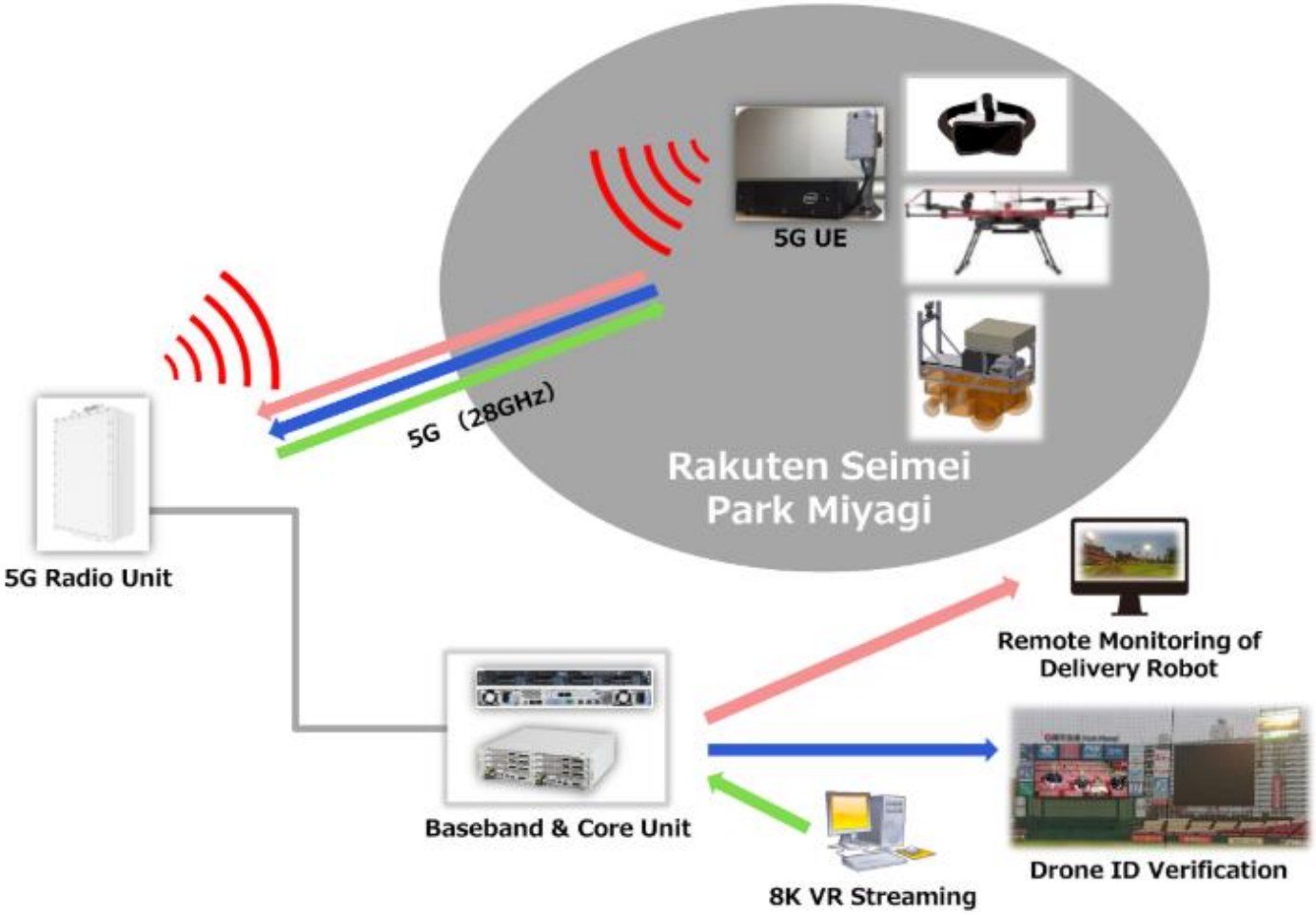


LG U+/KDDI, Remote Control

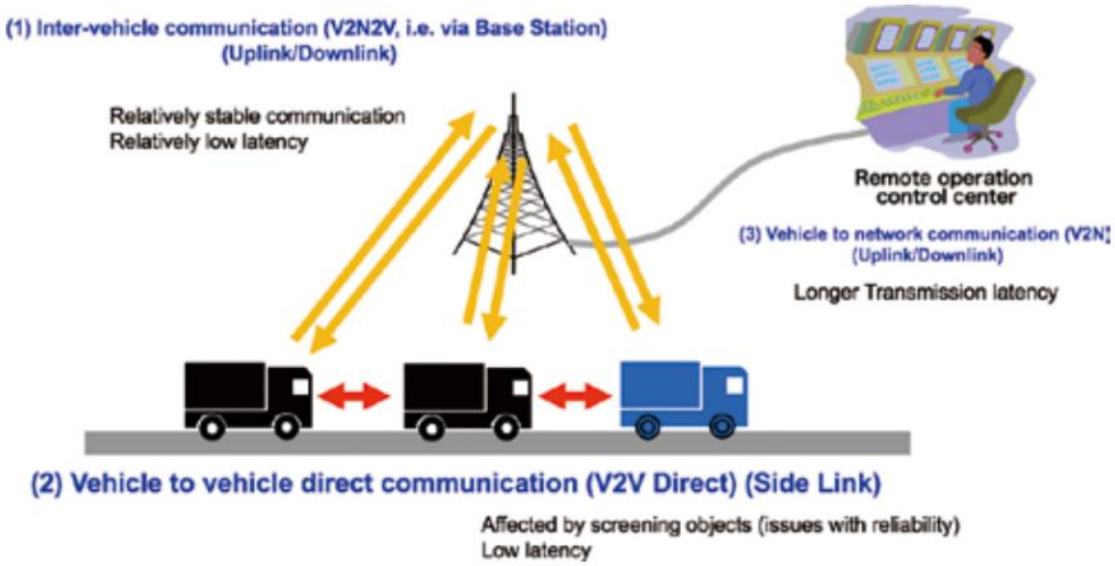




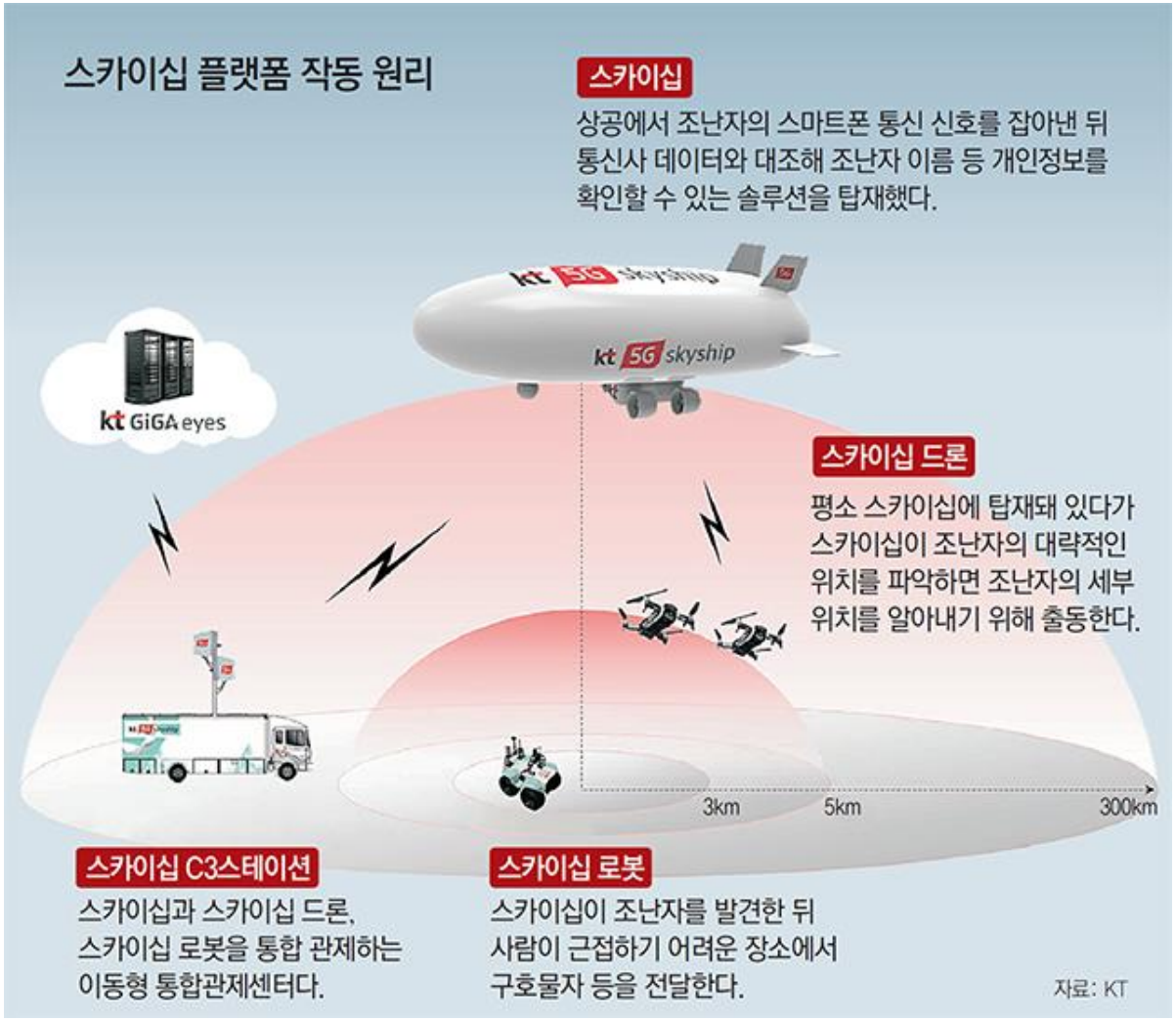
Rakuten, mmWave 활용



SoftBank, 5G 기반 군집주행

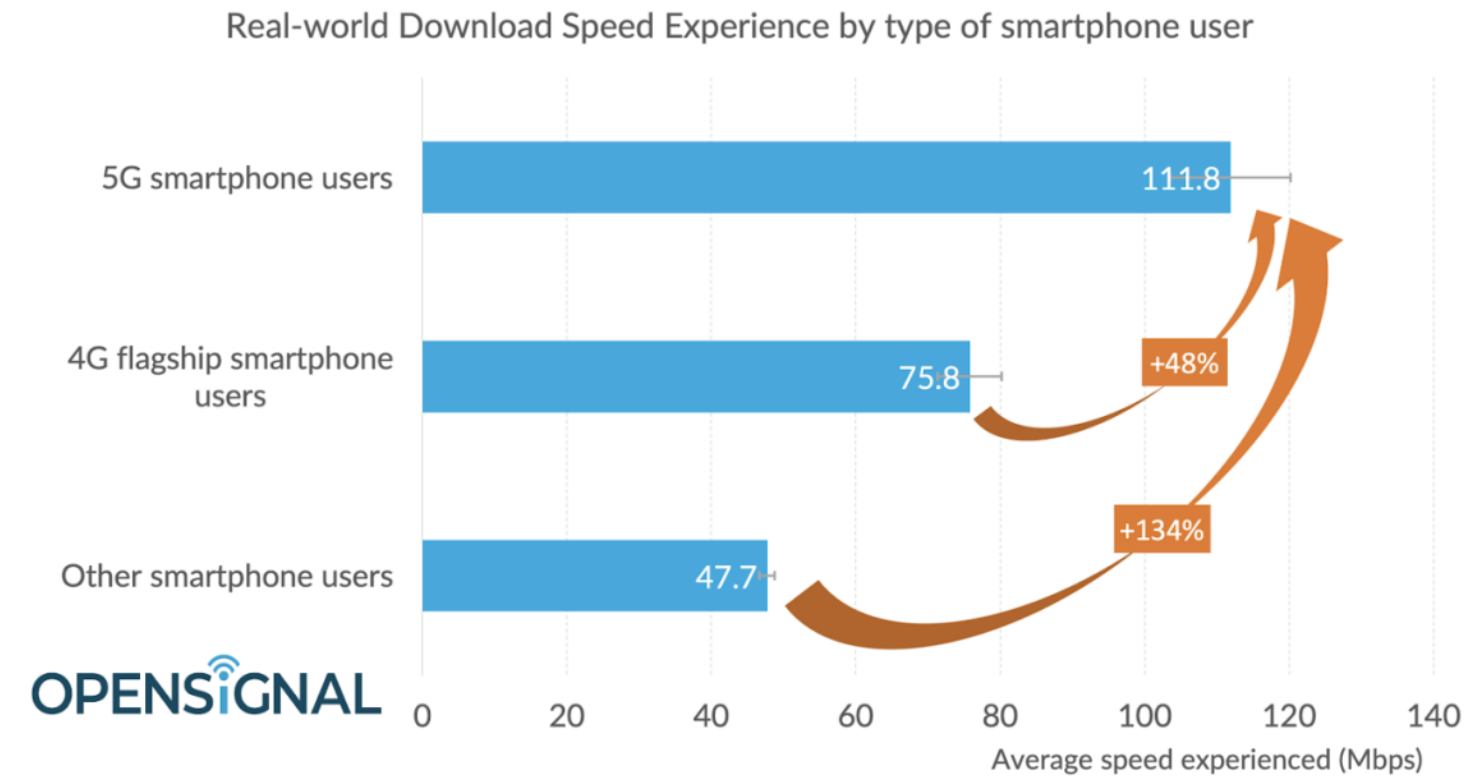


KT, Skyship


스카이십 플랫폼 작동 원리
스카이십
상공에서 조난자의 스마트폰 통신 신호를 잡아낸 뒤 통신사 데이터와 대조해 조난자 이름 등 개인정보를 확인할 수 있는 솔루션을 탑재했다.
kt 5G skyship
kt GiGA eyes
스카이십 드론
평소 스카이십에 탑재돼 있다가 스카이십이 조난자의 대략적인 위치를 파악하면 조난자의 세부 위치를 알아내기 위해 출동한다.
3km
5km
300km
스카이십 C3스테이션
스카이십과 스카이십 드론, 스카이십 로봇을 통합 관제하는 이동형 통합관제센터다.
스카이십 로봇
스카이십이 조난자를 발견한 뒤 사람이 근접하기 어려운 장소에서 구호물자 등을 전달한다.
자료: KT

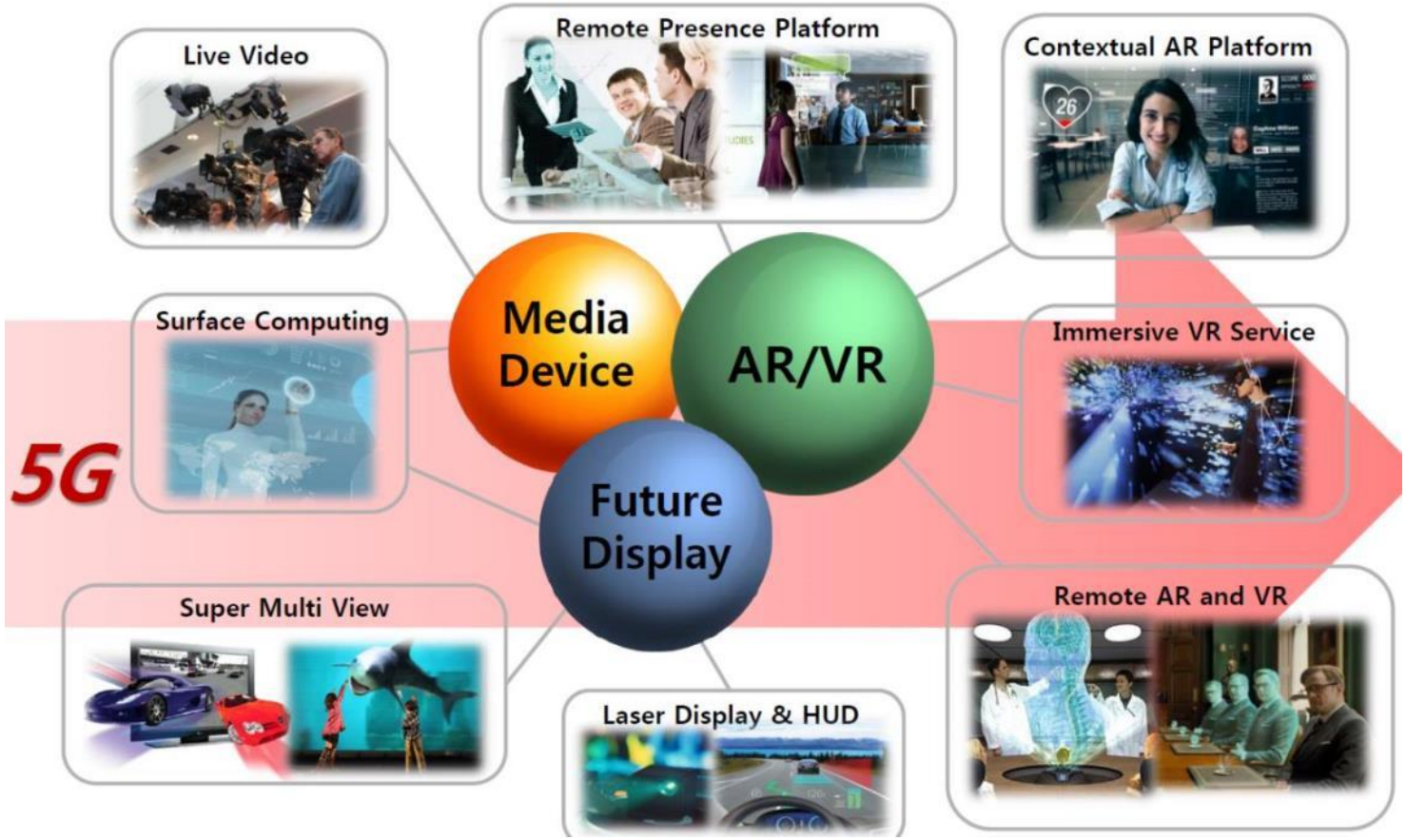
eMBB

5G 데이터 속도



Data collection period April 1 – June 12, 2019. Geography: South Korean cities where 5G has launched.

미디어 서비스



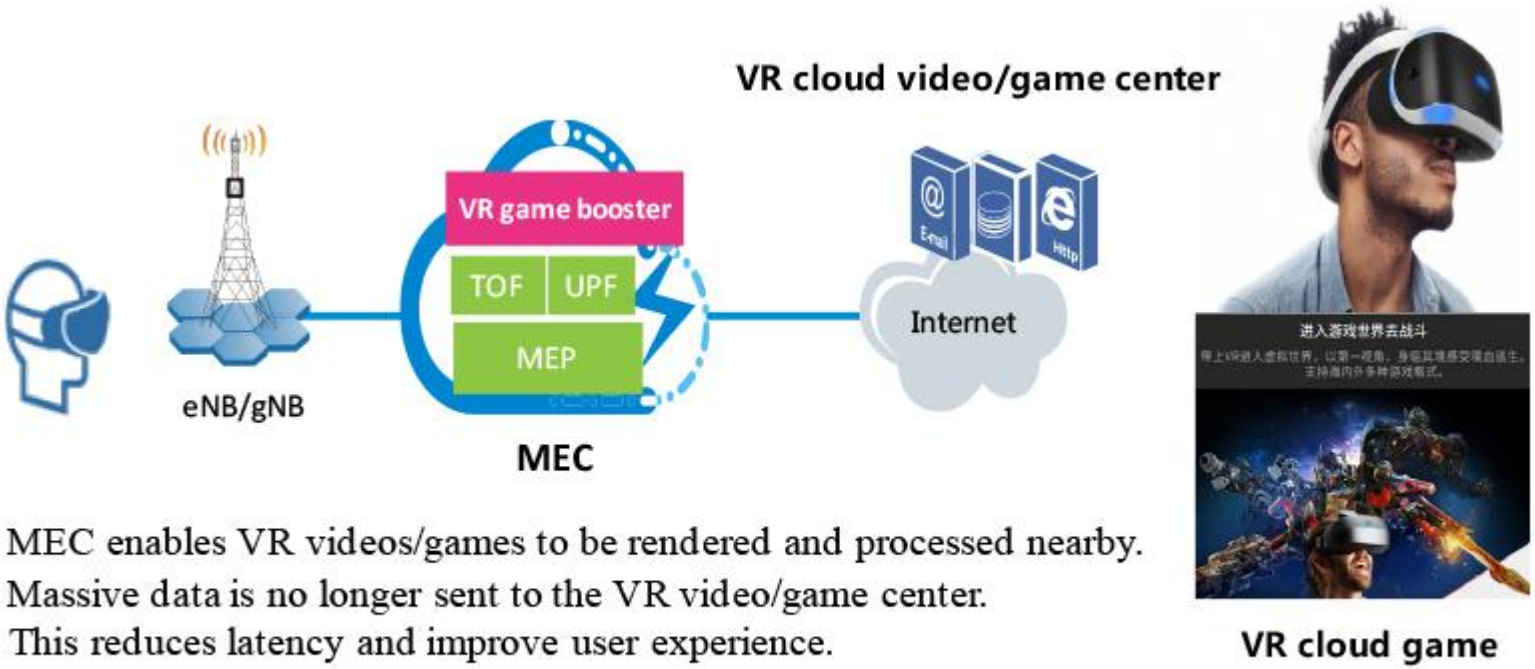
* eMBB: enhanced Mobile Broadband

Wide View, Multi-View

eMBB

KT, FITT 360

5G Cloud Gaming

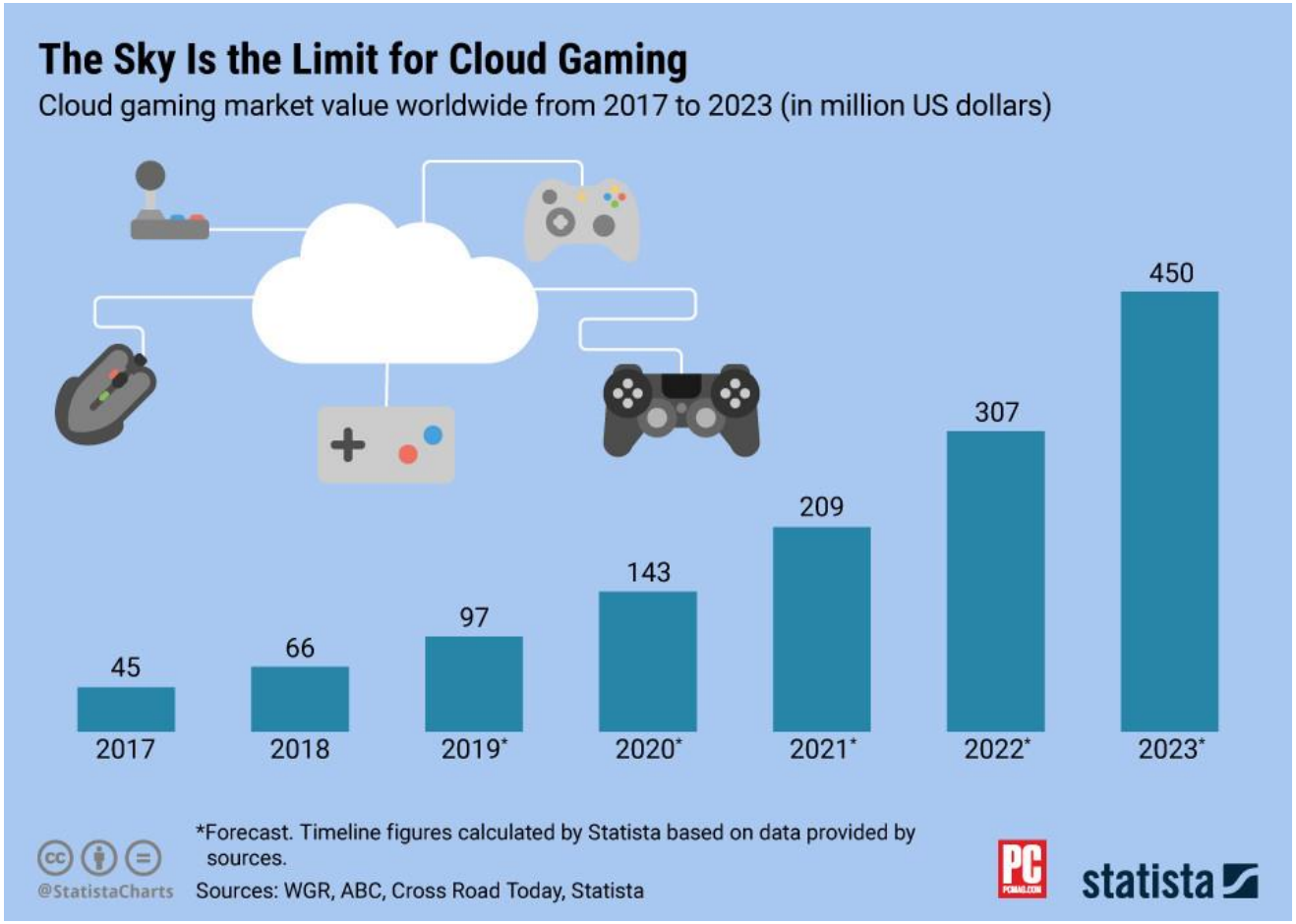


- MEC enables VR videos/games to be rendered and processed nearby.
- Massive data is no longer sent to the VR video/game center. This reduces latency and improve user experience.

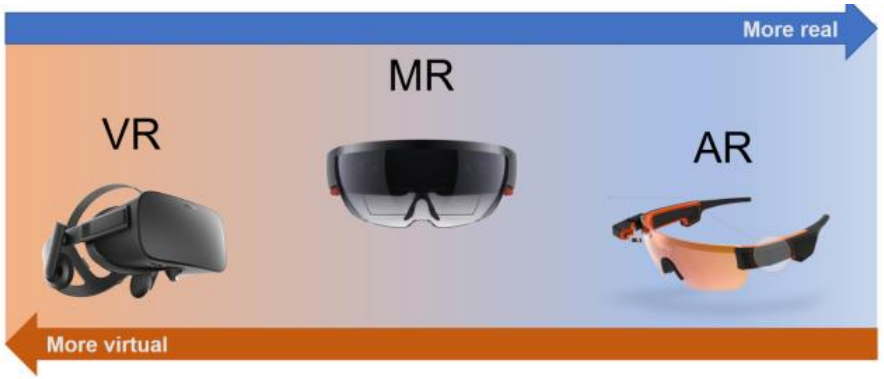
Fig. 1. Architecture of MEC-based cloud VR game.

* MEC: Mobile Edge Computing

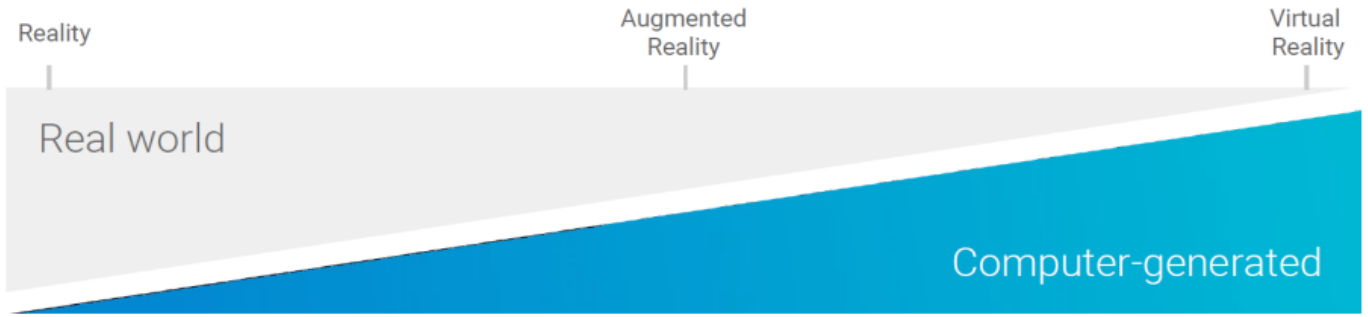
Cloud Gaming Market



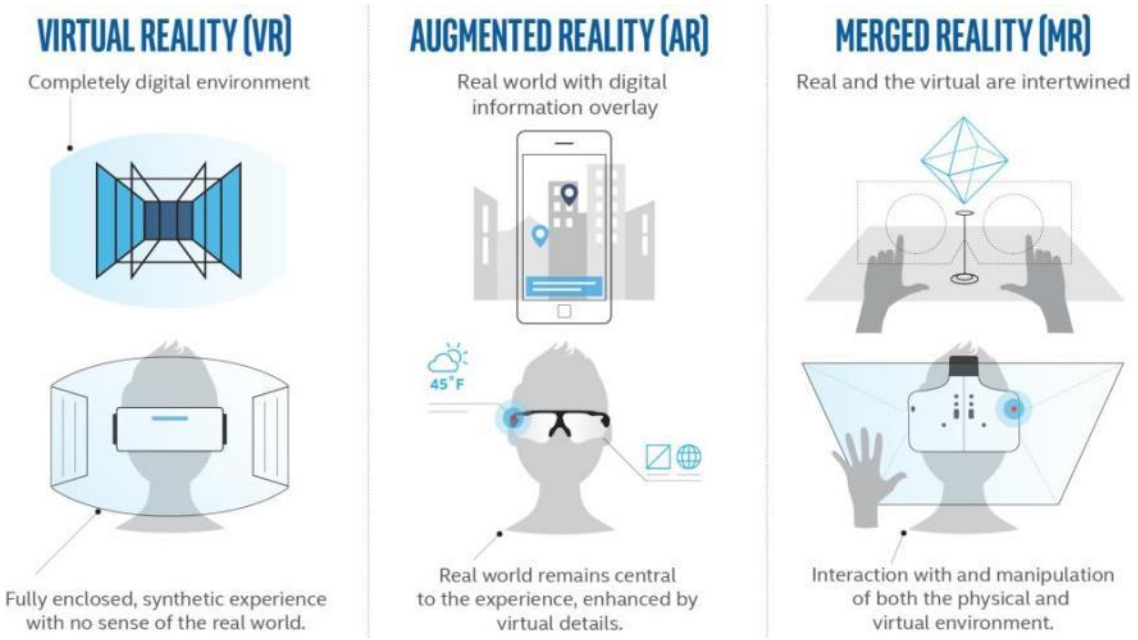

The Virtuality Continuum
Umbrella category that covers VR, AR and MR
XR
MR
Real and the virtual world are intertwined
VR
AR


More real
MR
VR
AR
More virtual


IMMERSIVE REALITIES
VR, AR, MR, 360° Video
Virtual Reality (VR)
Augmented Reality (AR)
Mixed Reality (MR)
360° Video


Reality
Augmented Reality
Virtual Reality
Real world
Computer-generated

AR/VR/MR/XR



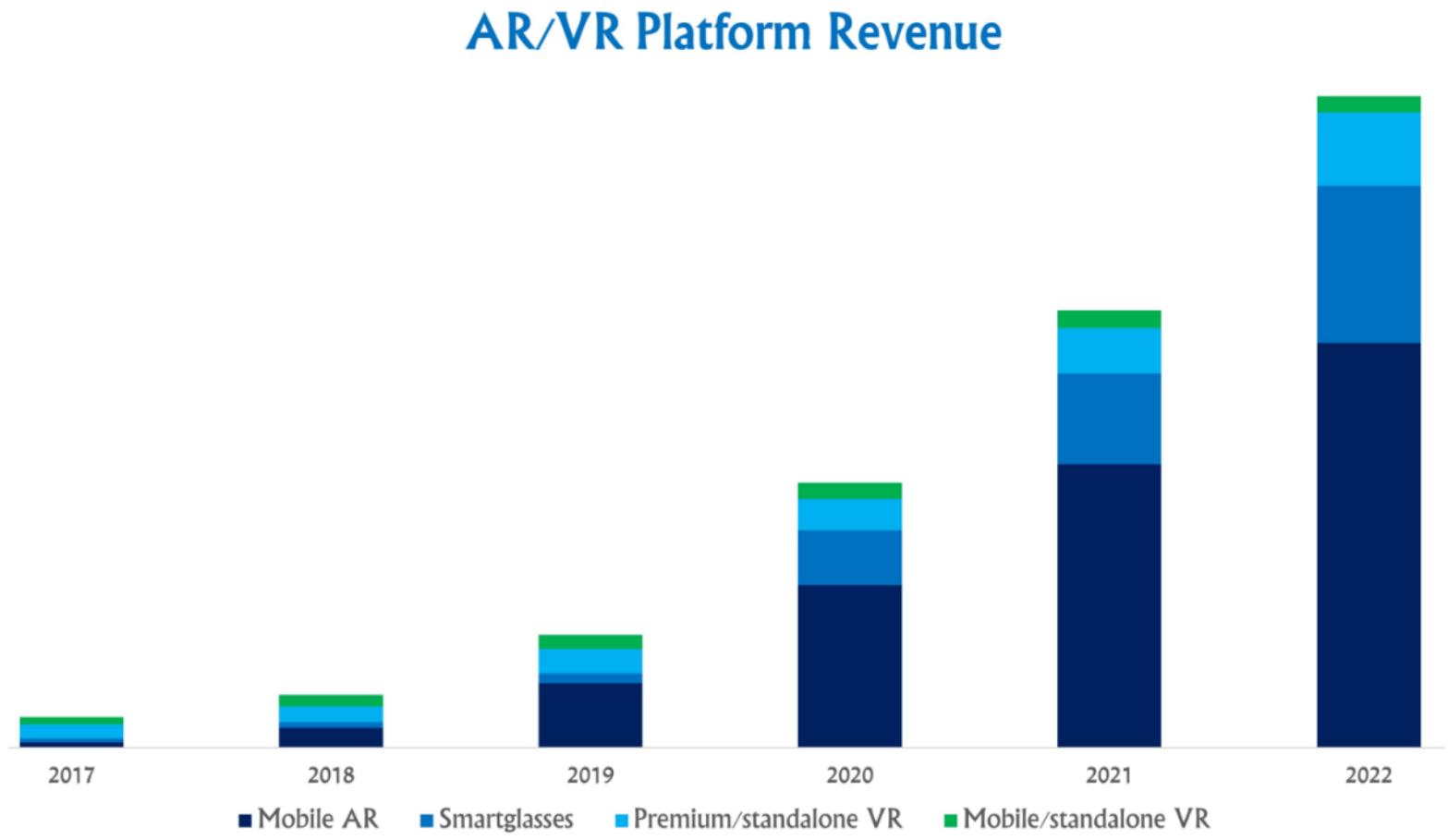
- VR: 시야가 밀폐된 디바이스를 사용하여 컴퓨터에서 생성되는 가상환경만 볼 수 있고, 현실환경과 Interaction은 없음

- AR: 현실 이미지와 가상 이미지를 결합하여 실시간 상호작용(Interaction)이 가능하고, 3차원 현실공간에 놓인 가상정보
  - AR 기능 제공을 위한 디바이스는 Smartphone, Tablet, Smart Glass 등이 있으며, Mobile AR은 Smartphone이나 Tablet을 이용하여 AR 서비스를 제공하는 방법

- MR: 일반적으로 카메라가 탑재된 시야가 밀폐된 VR 디바이스가 사용되며, 디바이스 센서를 이용하여 손을 이용한 Gesture Control 등을 통하여 현실과 가상 정보간 상호 Interaction이 가능한 방법

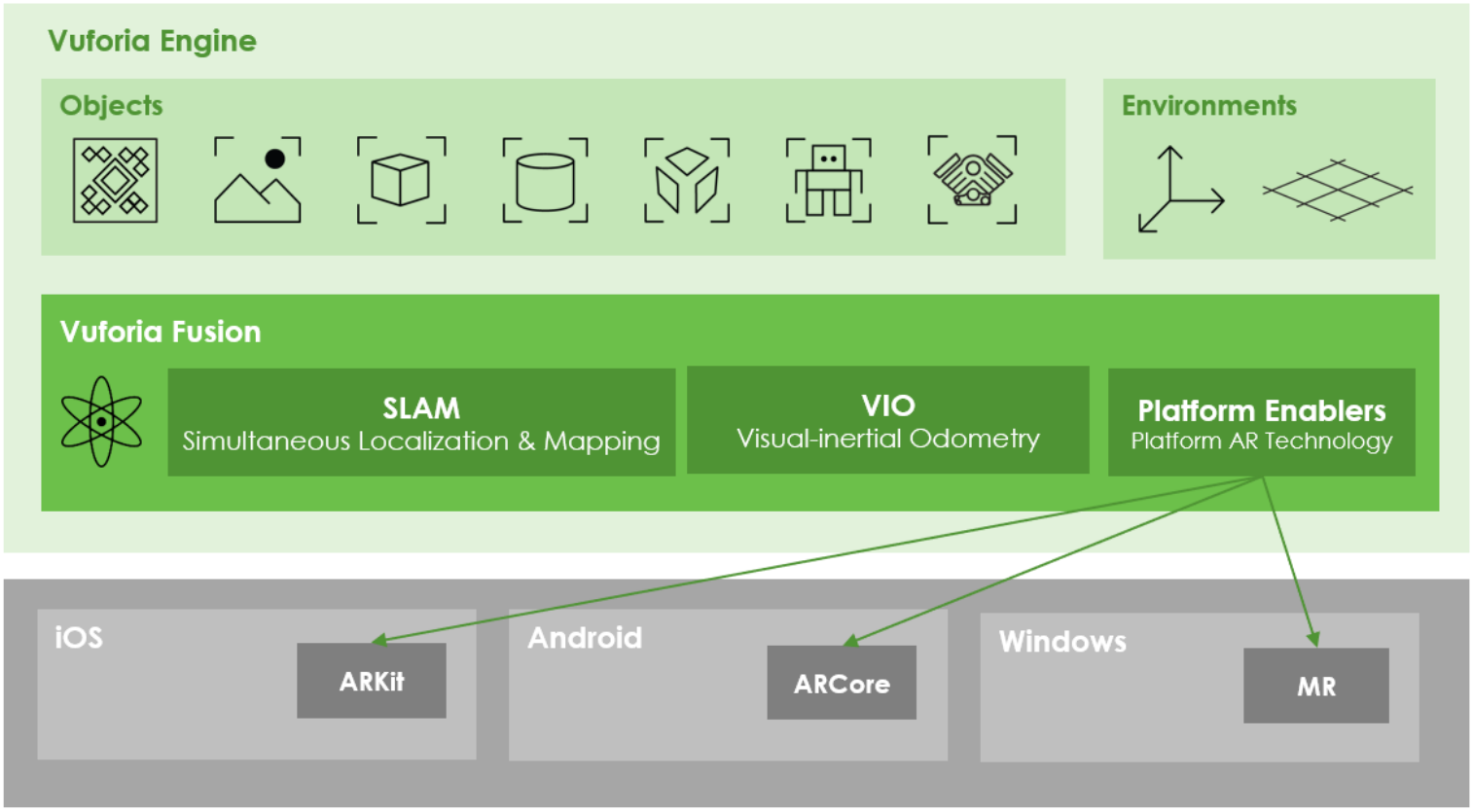
- AR, VR, MR, XR은 가상환경이지만, 사용자를 현실환경처럼 느끼게 만들어서 빠져들게 하는 'Immersive Experience'를 제공

AR/VR 시장


AR/VR Platform Revenue
2017
2018
2019
2020
2021
2022
Mobile AR
Smartglasses
Premium/standalone VR
Mobile/standalone VR

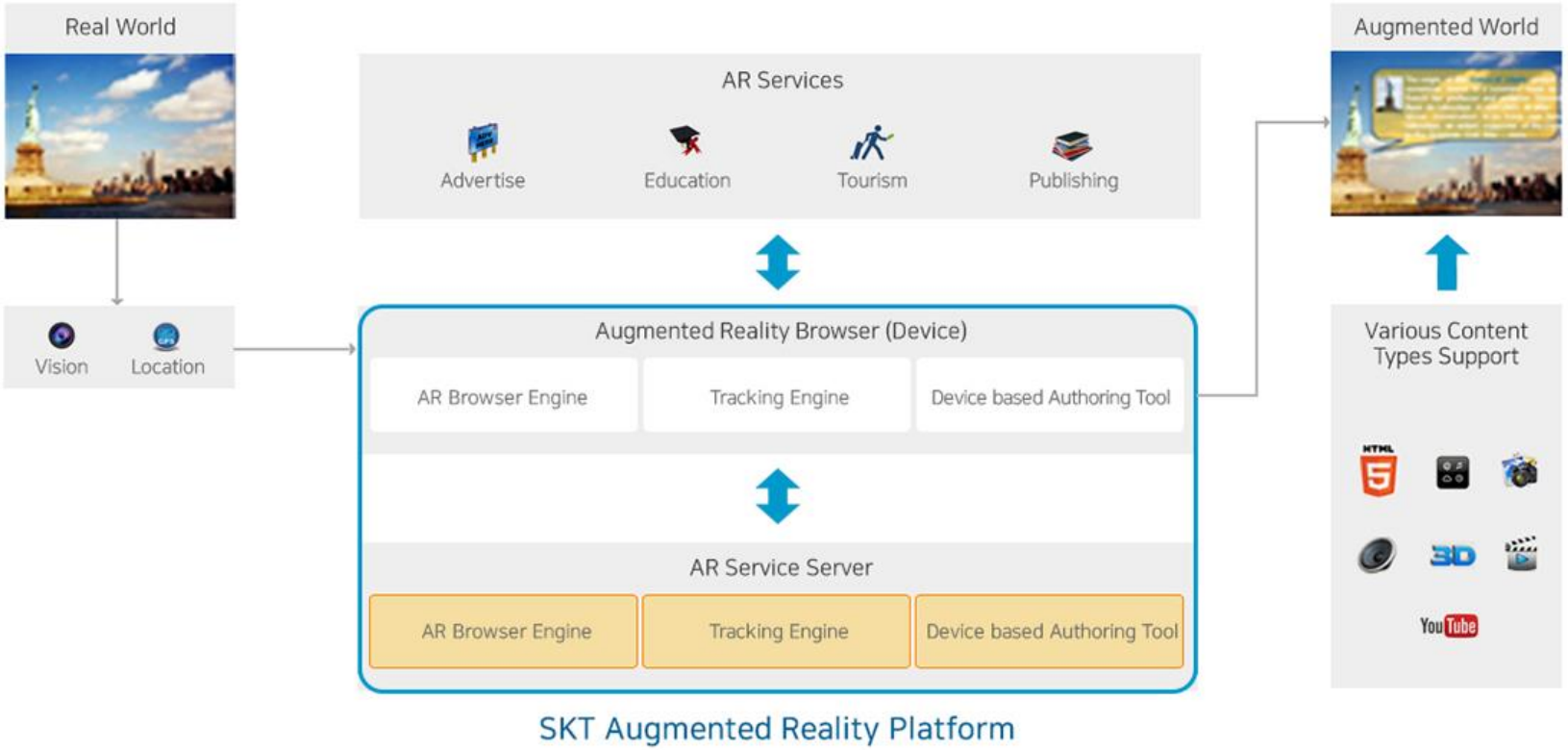
AR/VR Platform 예(1)

eMBB+URLLC

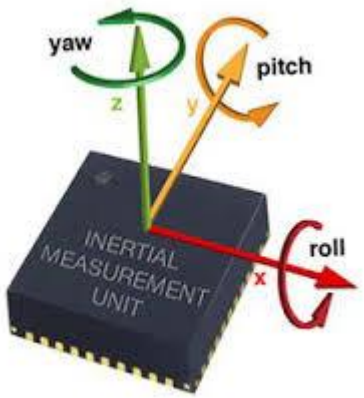


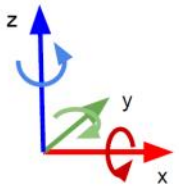
AR/VR Platform 예(2)

eMBB+URLLC



VIO를 위한 Motion Tracking 예



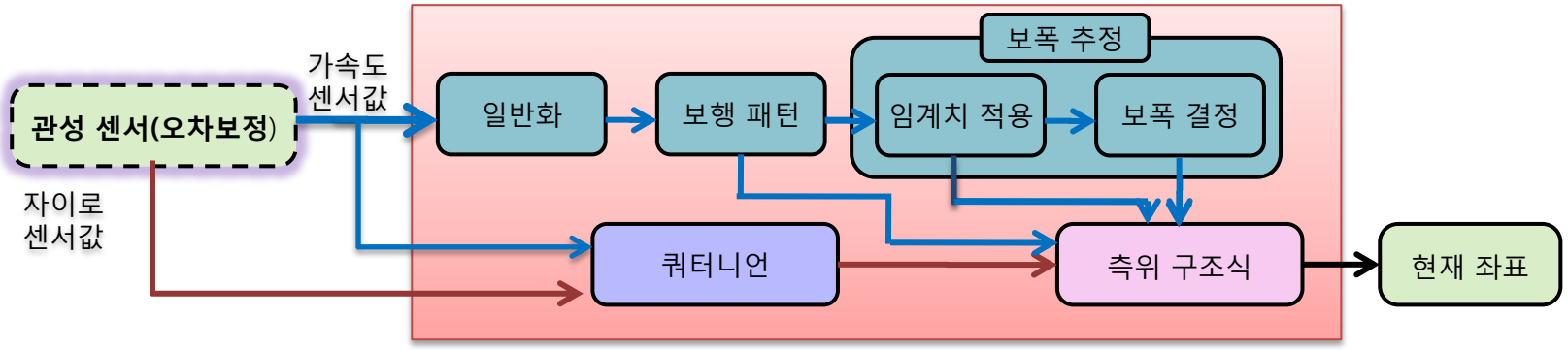


Gyroscope

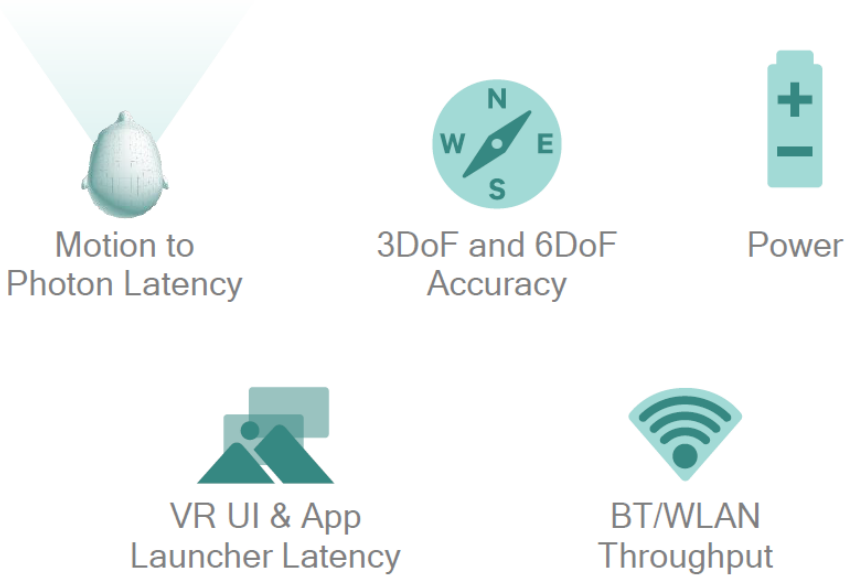
rotational velocity → ∫ → rotation angle

Accelerometer

acceleration → ∫ → velocity → ∫ → position



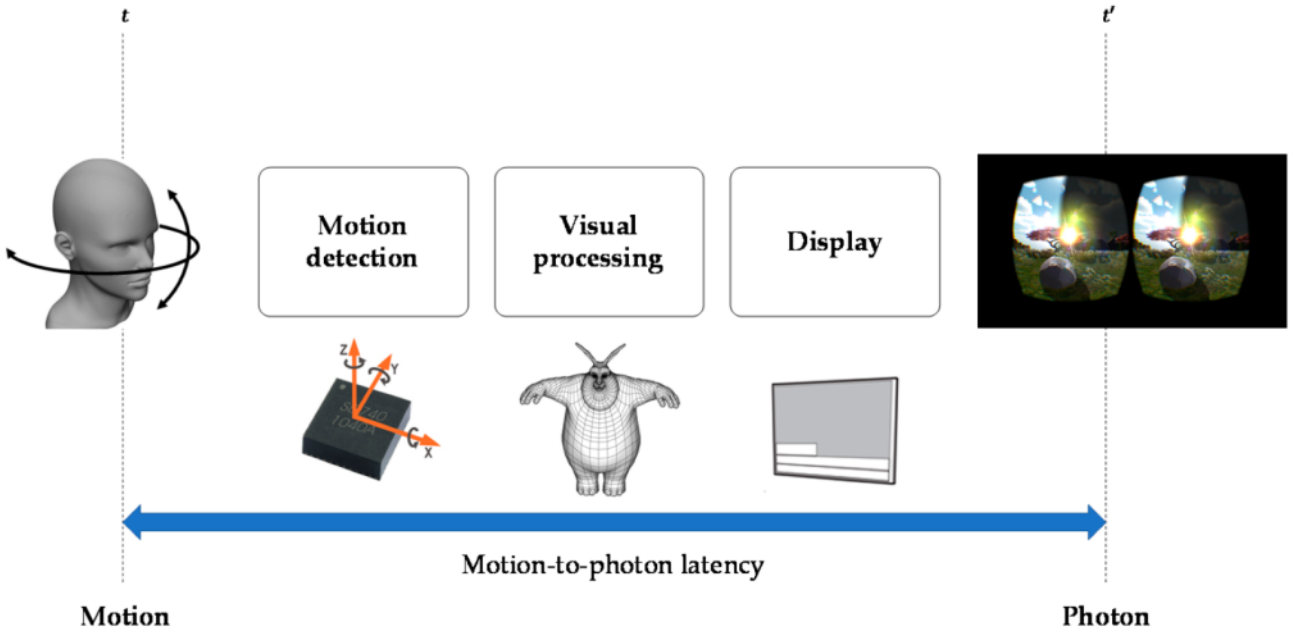
AR/VR/MR/XR 성능평가 지표



< AR/VR/MR의 대표적인 성능평가 지표 >

- Video Processing(예, 1080p 30frame/second
- Display 관련
  - Display Resolution
  - Display Size
  - Refresh Rate(예, 90Hz
- FOV(Field of View)
- DoF(Degree of Feedom)
- Motion to Photon Latency
- Power Consumption(Battery Life)
- 무게, 착용감, 열배출(통풍) 등

Motion to Photon



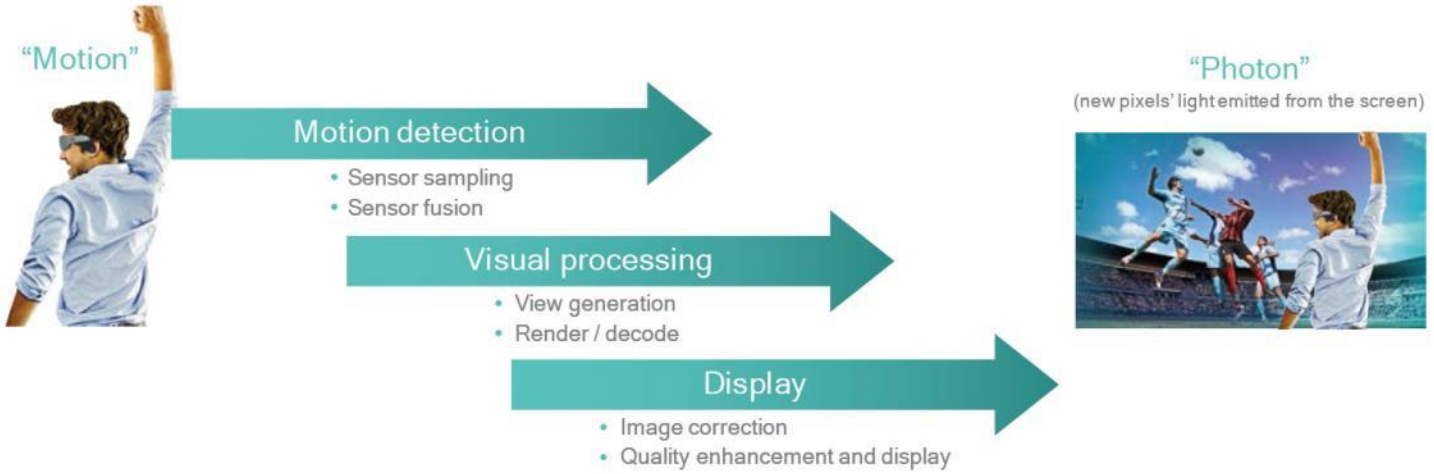


Figure 10: The motion to photon path includes many tasks.

FWA: Fixed Wireless Access

eMBB

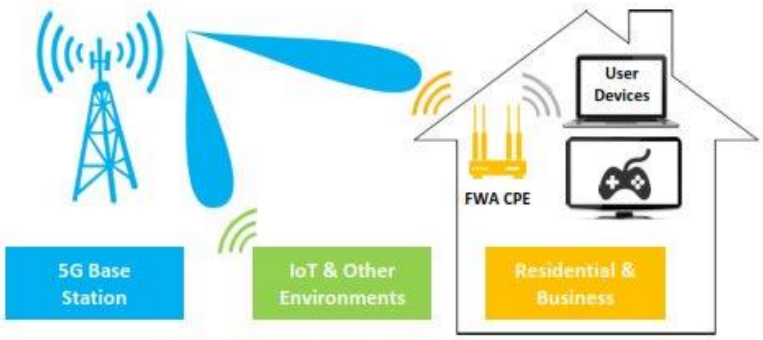


Figure 7: 5G-Based FWA Application Scenarios

Source: SNS Research

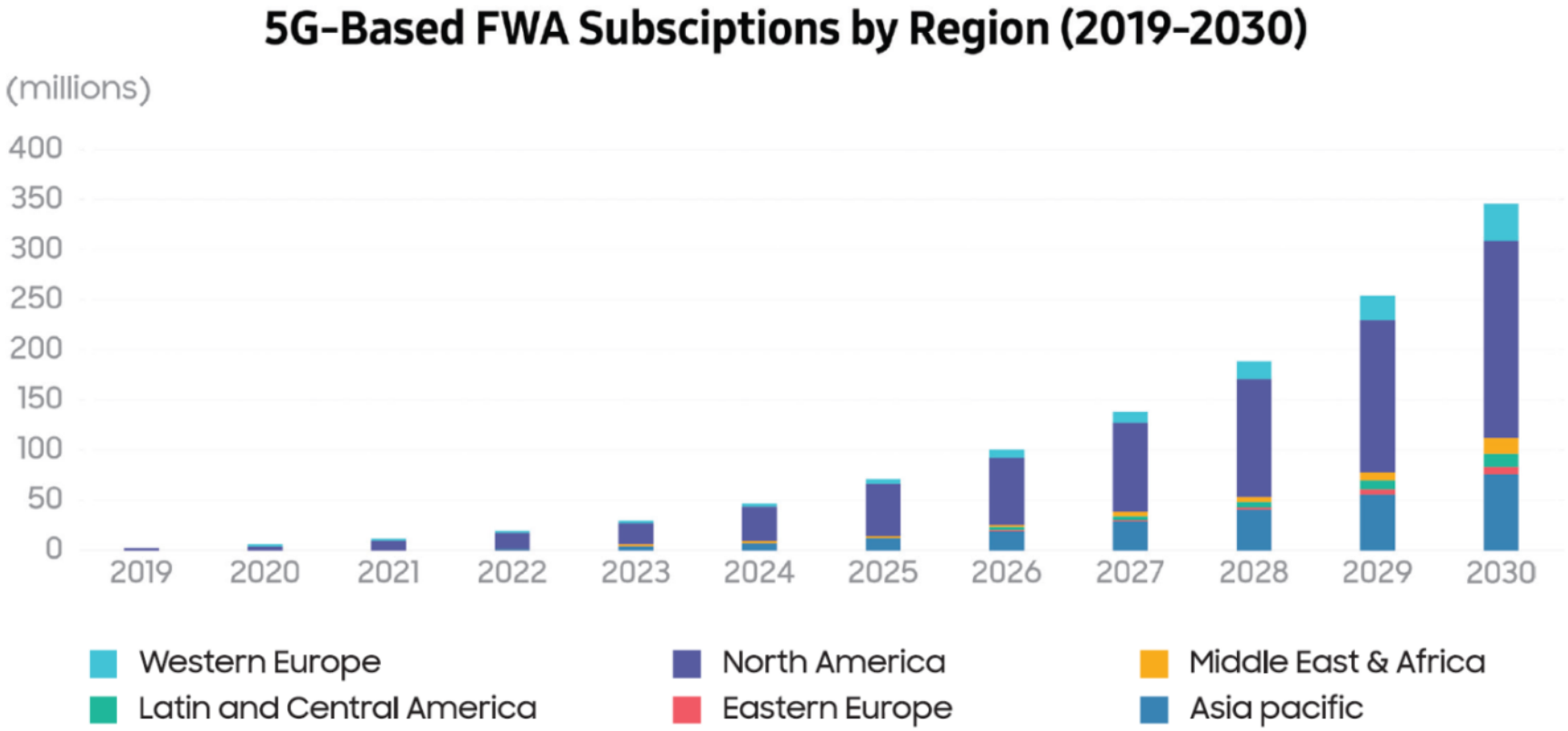
FWA Cost

Wireline Network

5G FWA Network

Greatly Reduces CAPEX/OPEX, Deployment Times (Weeks → Days)

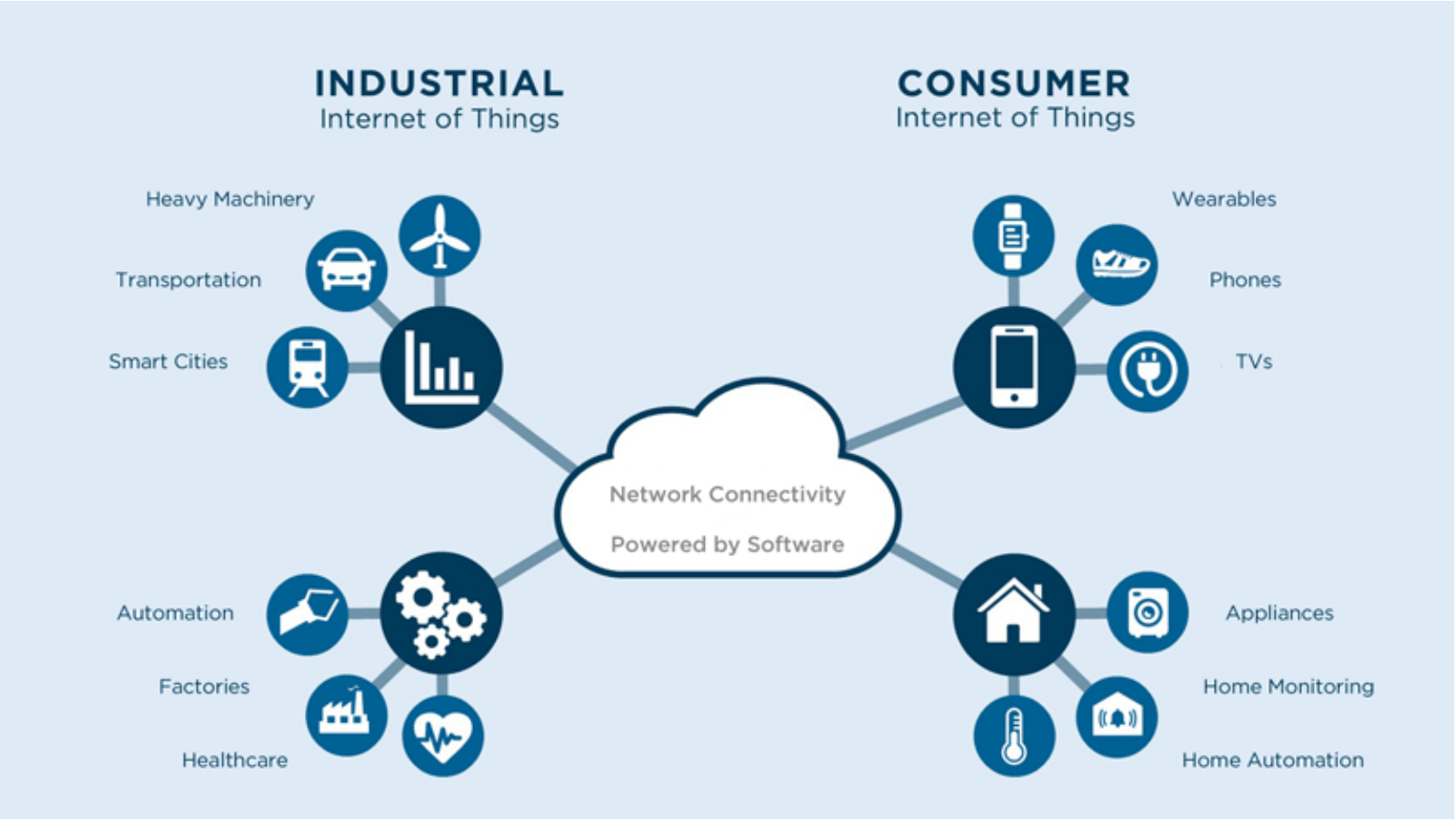
FWA 가입자 예측



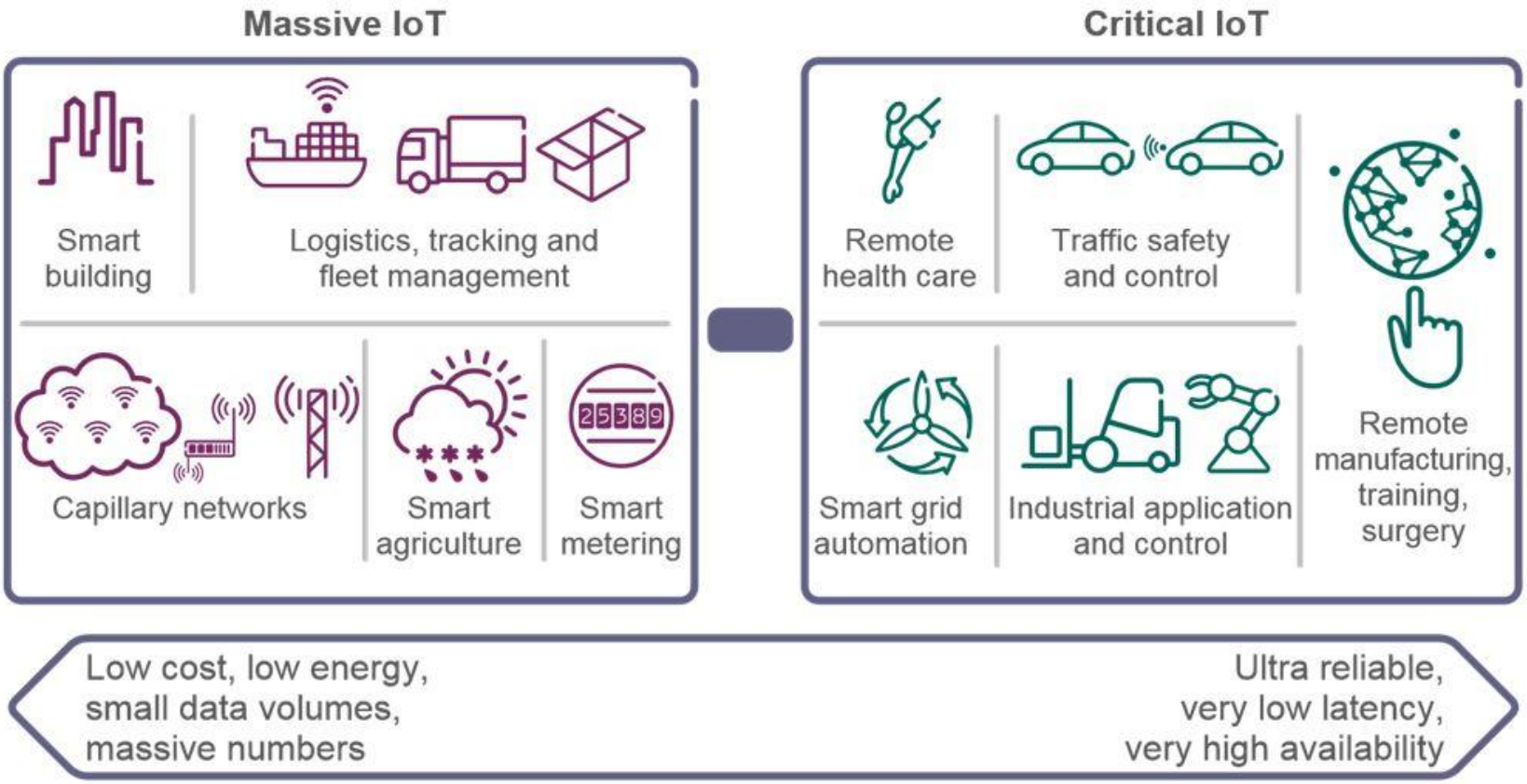
(Source : SNS Telecom)

mMTC

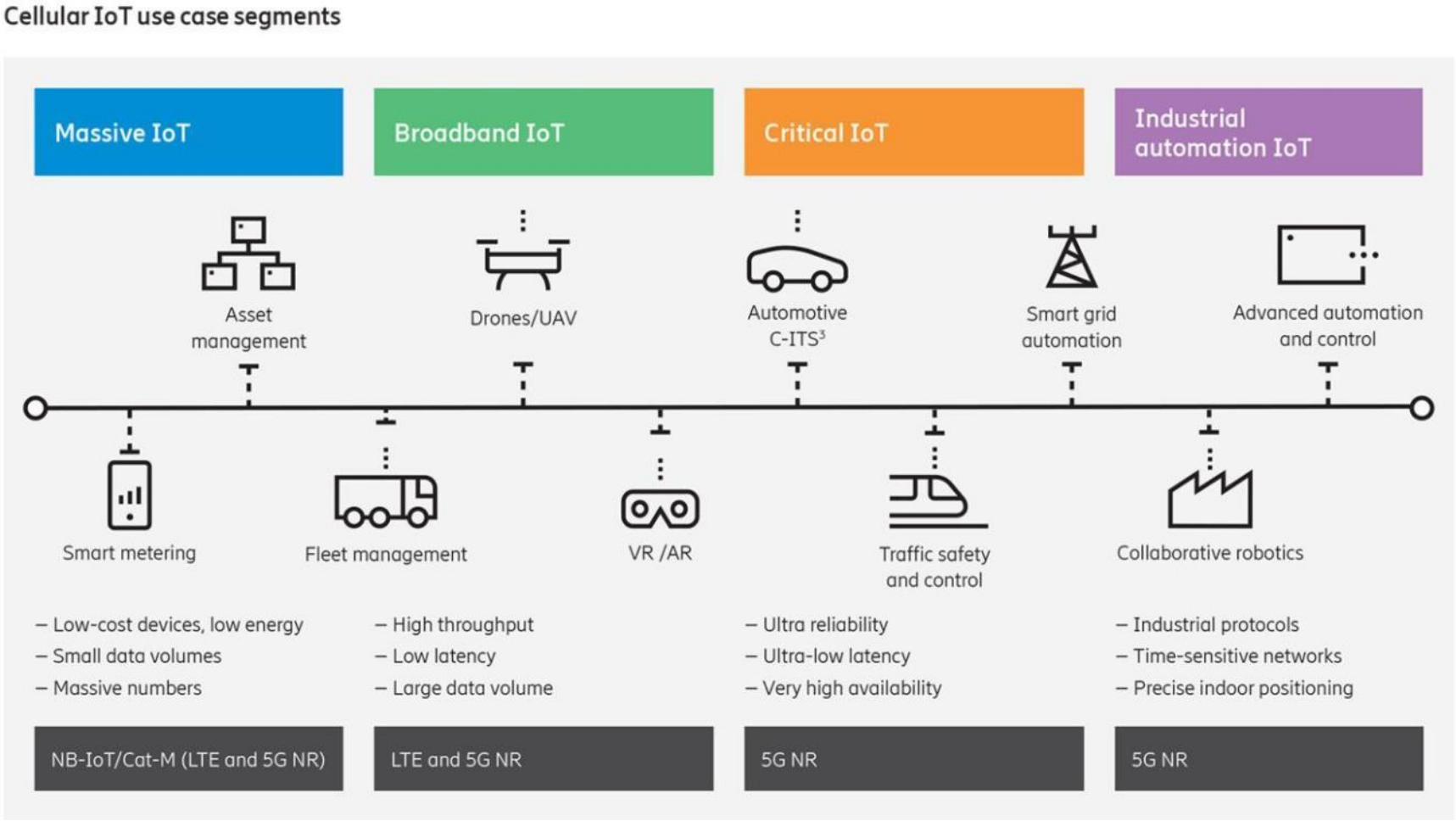
IoT 서비스 분류


INDUSTRIAL
Internet of Things
CONSUMER
Internet of Things
Heavy Machinery
Transportation
Smart Cities
Wearables
Phones
TVs
Network Connectivity
Powered by Software
Automation
Factories
Healthcare
Appliances
Home Monitoring
Home Automation

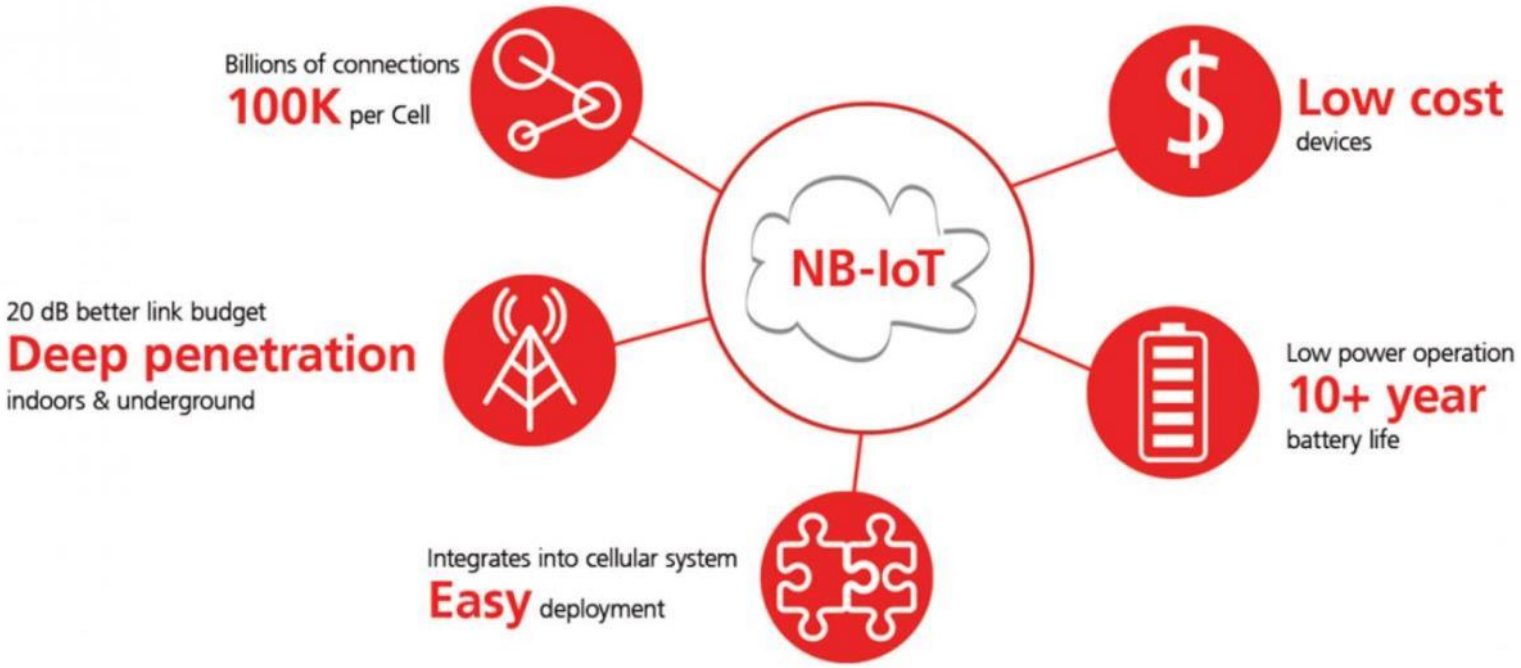
Cellular IoT 서비스 분류(1)



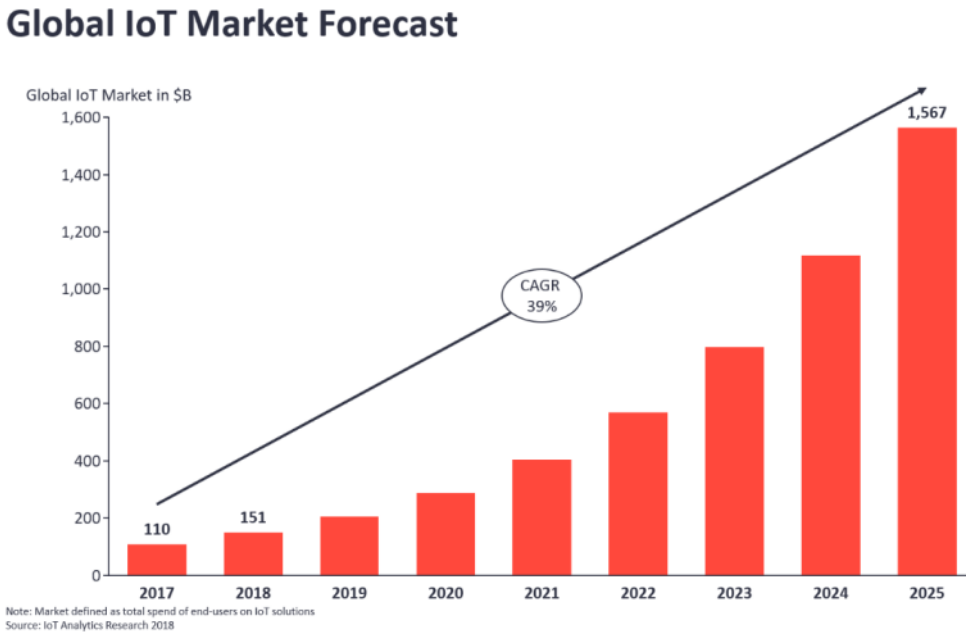
Cellular IoT 서비스 분류(2)

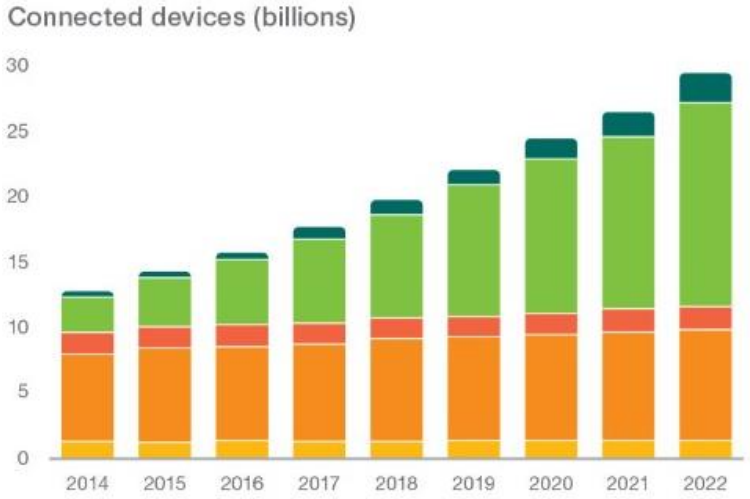


IoT가 지향하는 목표


Billions of connections
100K per Cell
NB-IoT
Low cost
devices
20 dB better link budget
Deep penetration
indoors & underground
Low power operation
10+ year
battery life
Integrates into cellular system
Easy deployment

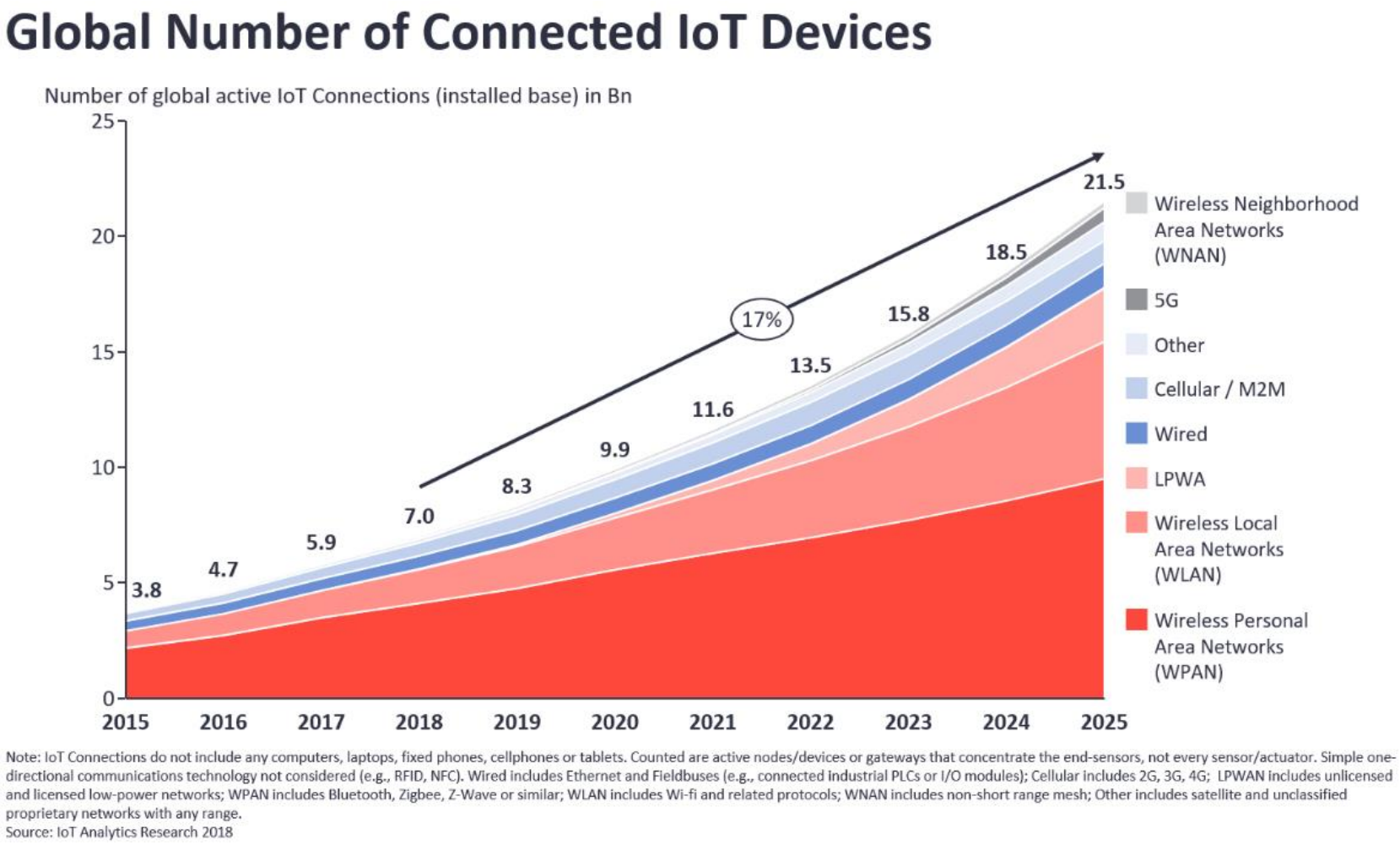
IoT 시장(1)





	2016	2022	CAGR
Wide-area IoT	0.4	2.1	30%
Short-range IoT	5.2	16	20%
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.3	8.6	3%
Fixed phones	1.4	1.3	0%
	16 billion	29 billion	10%

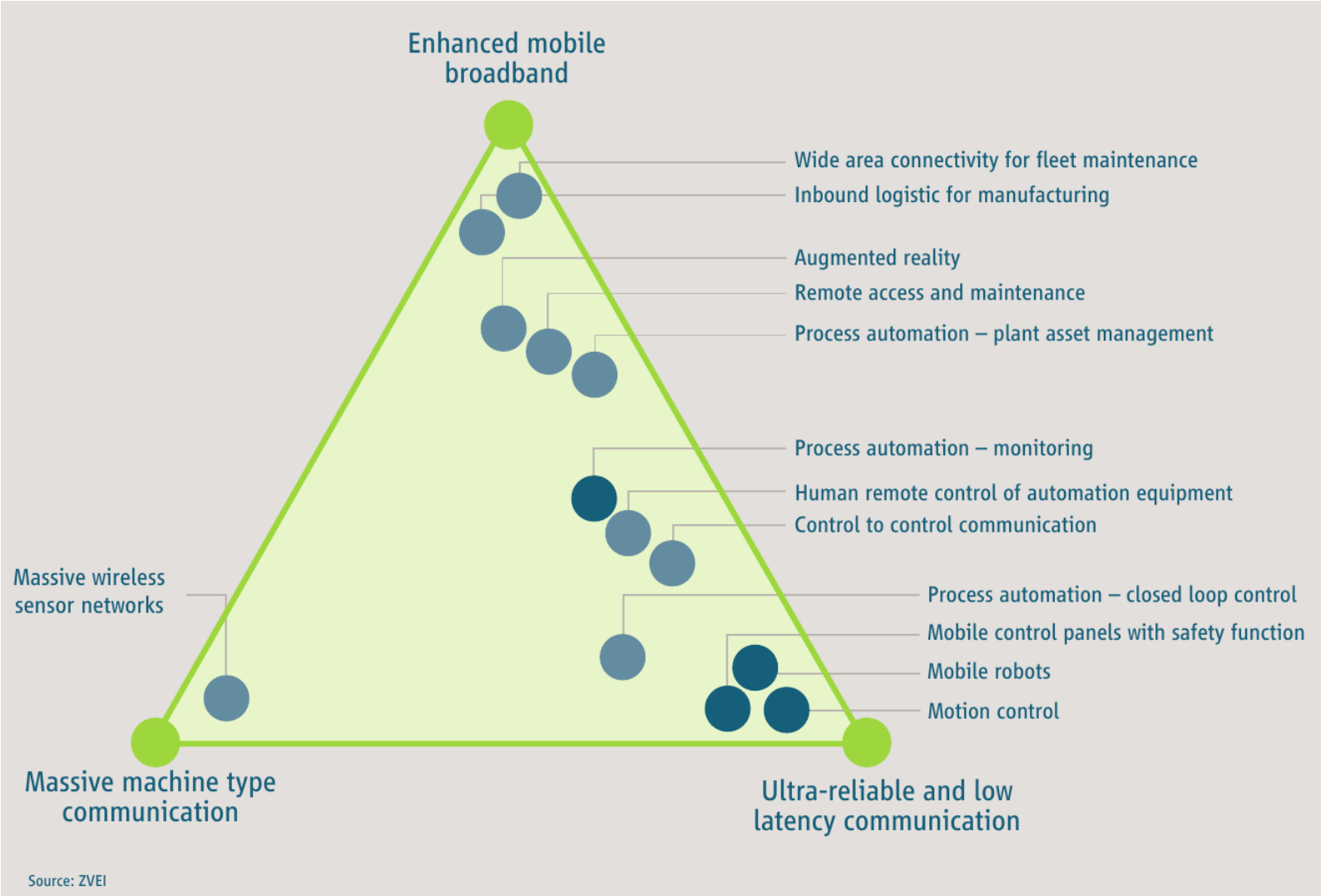
IoT 시장(2)



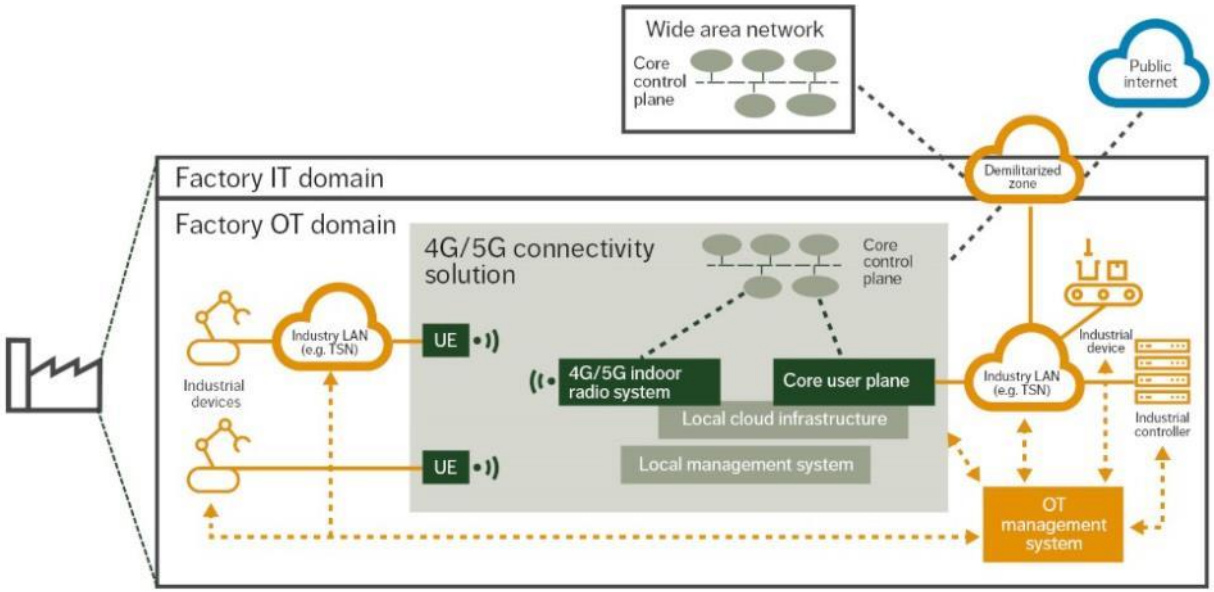
Note: IoT Connections do not include any computers, laptops, fixed phones, cellphones or tablets. Counted are active nodes/devices or gateways that concentrate the end-sensors, not every sensor/actuator. Simple one-directional communications technology not considered (e.g., RFID, NFC). Wired includes Ethernet and Fieldbuses (e.g., connected Industrial PLCs or I/O modules); Cellular includes 2G, 3G, 4G; LPWAN includes unlicensed and licensed low-power networks; WPAN includes Bluetooth, Zigbee, Z-Wave or similar; WLAN includes Wi-fi and related protocols; WNAN includes non-short range mesh; Other includes satellite and unclassified proprietary networks with any range.
Source: IoT Analytics Research 2018

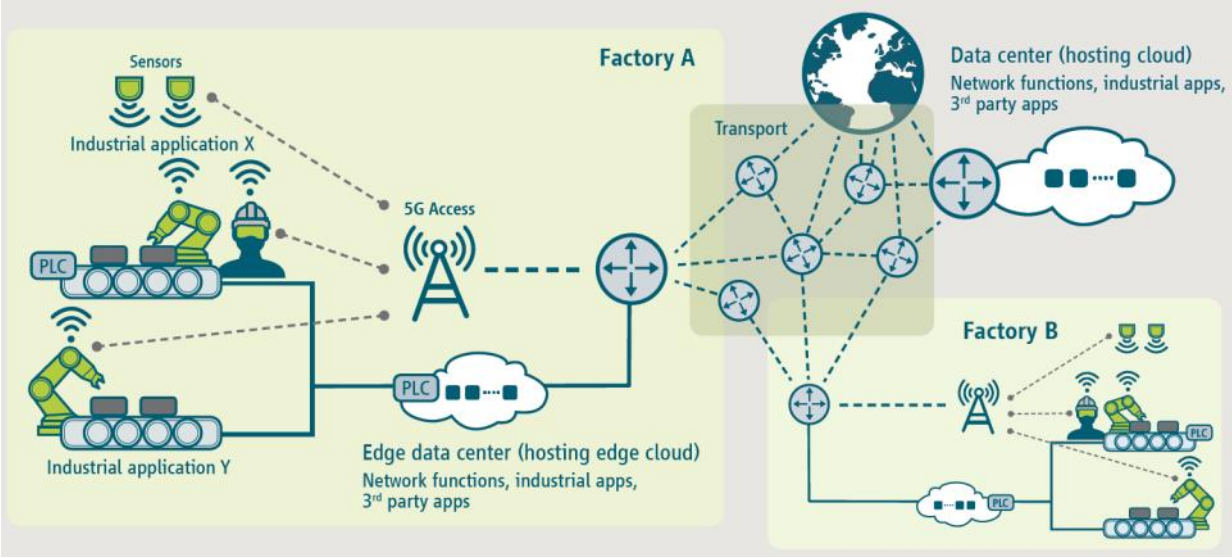
Smart Factory(1)

5G ACIA
5G Alliance for Connected Industries and Automation

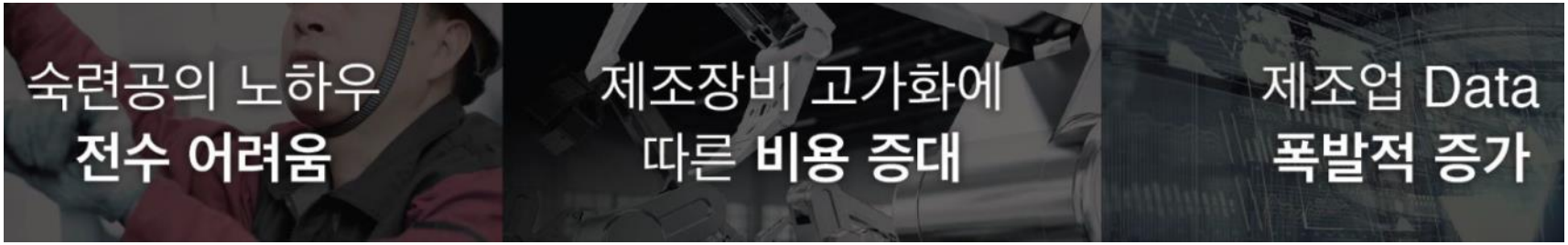


Smart Factory(2)



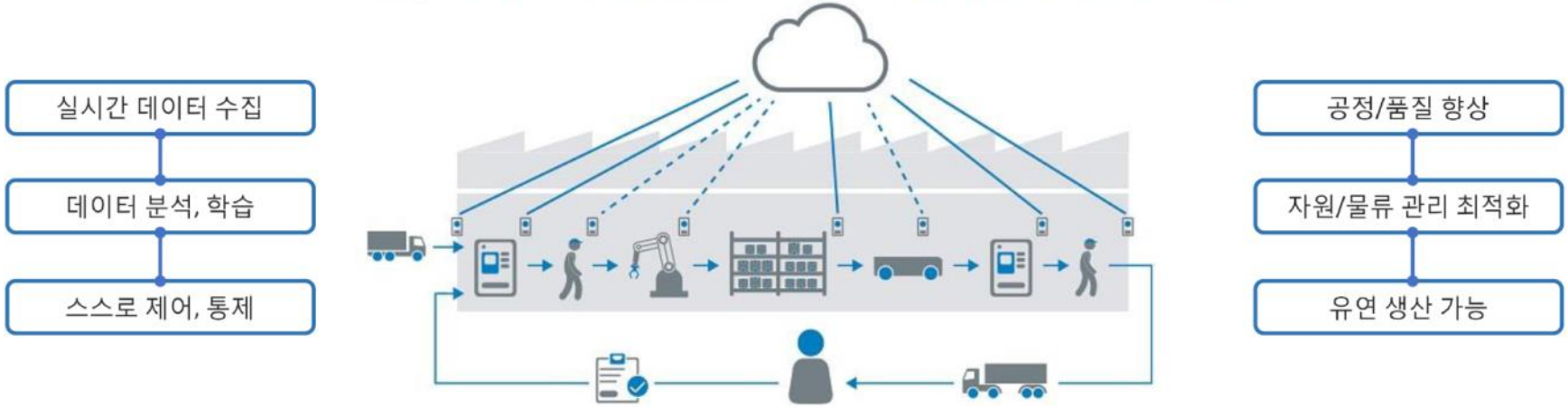


Why Smart Factory ?

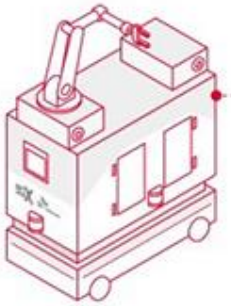


Smart Factory는 IT와 OT의 융합으로

자동화와 AI가 결합된 고도로 지능화된 생산 시스템



Smart Factory를 위한 기술요소



5G 다기능 협업 로봇

- 로봇 내부 공간에 스스로 제품을 적재하고 자율주행으로 이동
- 5G 망을 통해 인공지능 서버에서 다기능 협업 로봇에 명령 전달

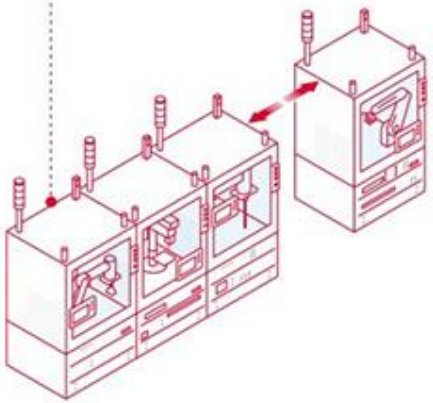
설비관리 AR

- 근로자가 AR 안경을 쓰면 설비, 부품 정보, 조립 매뉴얼 등을 실시간으로 확인
- 5G로 연결돼 움직임 범위가 넓고 안정성이 뛰어남

5G접목 솔루션 5종

5G 스마트 유연생산 설비

- 1.5m X 1m X 2m 크기의 공장 설비 모듈들이 생산라인 기능에 따라 다양하게 조합
- 생산, 검수, 포장 등을 담당하는 모듈 3~10개가 모여 하나의 제품 생산 라인 구성

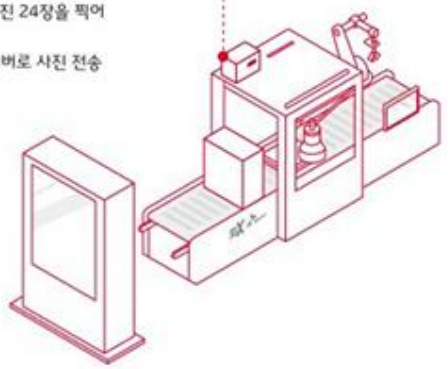


5G 소형 자율주행 로봇(AMR)

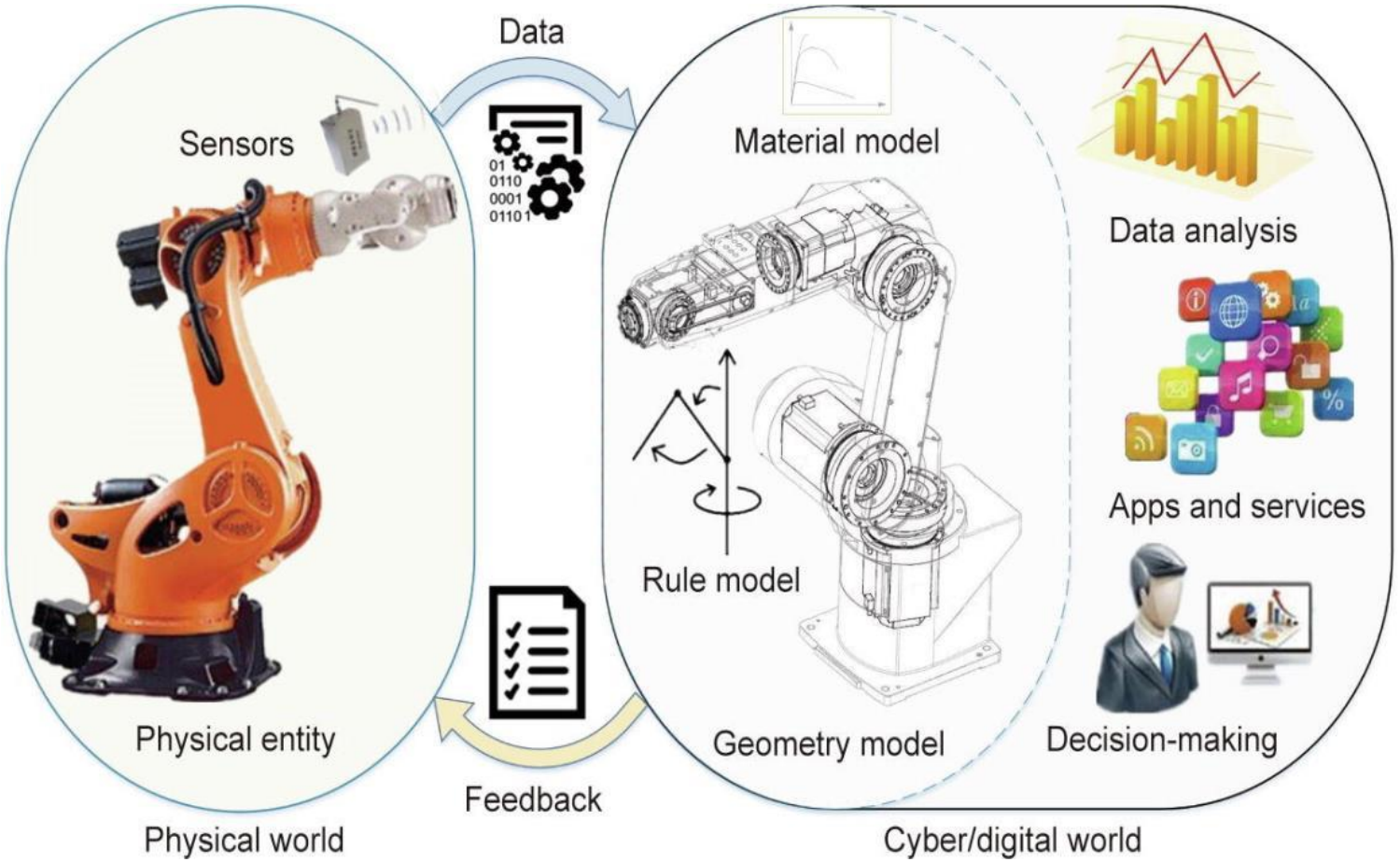
- 공장 내에서 사람을 돕기 위해 만들어진 소형 로봇
- 하단에 달린 바퀴 4개를 활용해 자율주행으로 좁은 공간에서도 능숙하게 움직임
- 5G 망을 통해 클라우드 서버로 사진 전송

5G-AI 머신비전

- 생산품이 컨베이어 벨트를 지나가는 동안 1200만 화소 카메라로 사진 24장을 찍어 AI가 결함 여부 확인
- 5G 망을 통해 클라우드 서버로 사진 전송

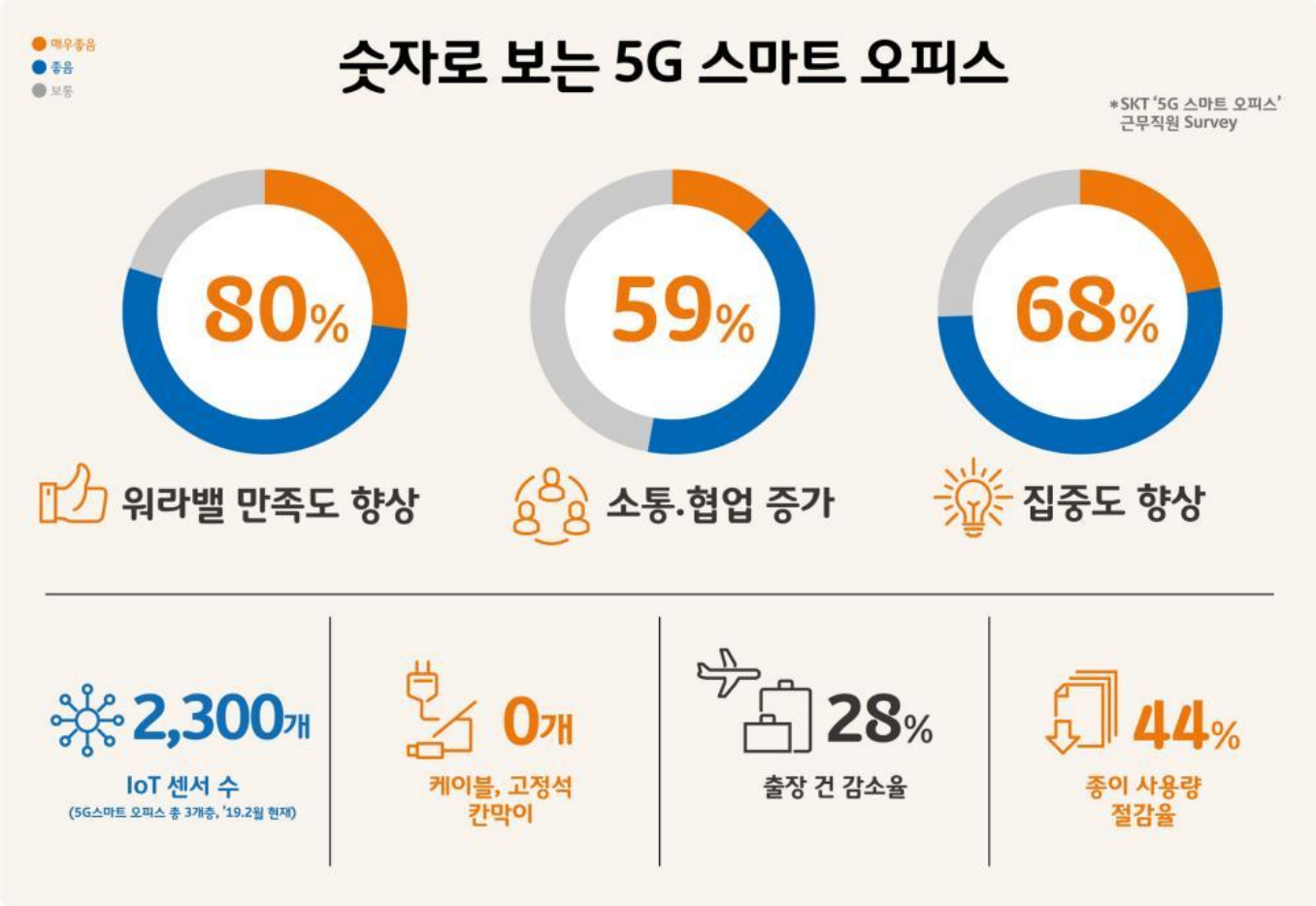


CPS, Digital Twin

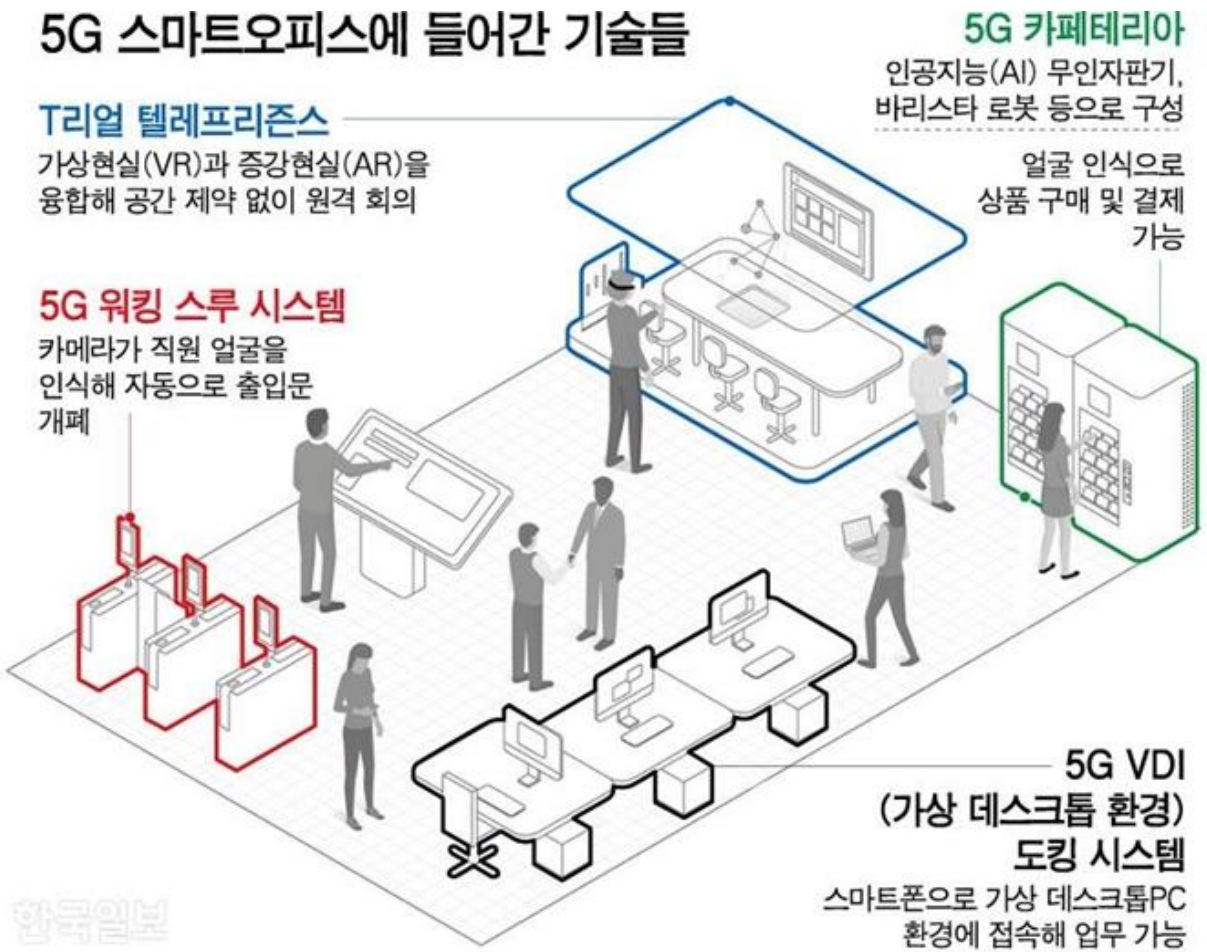


* CPS: Cyber Physical System

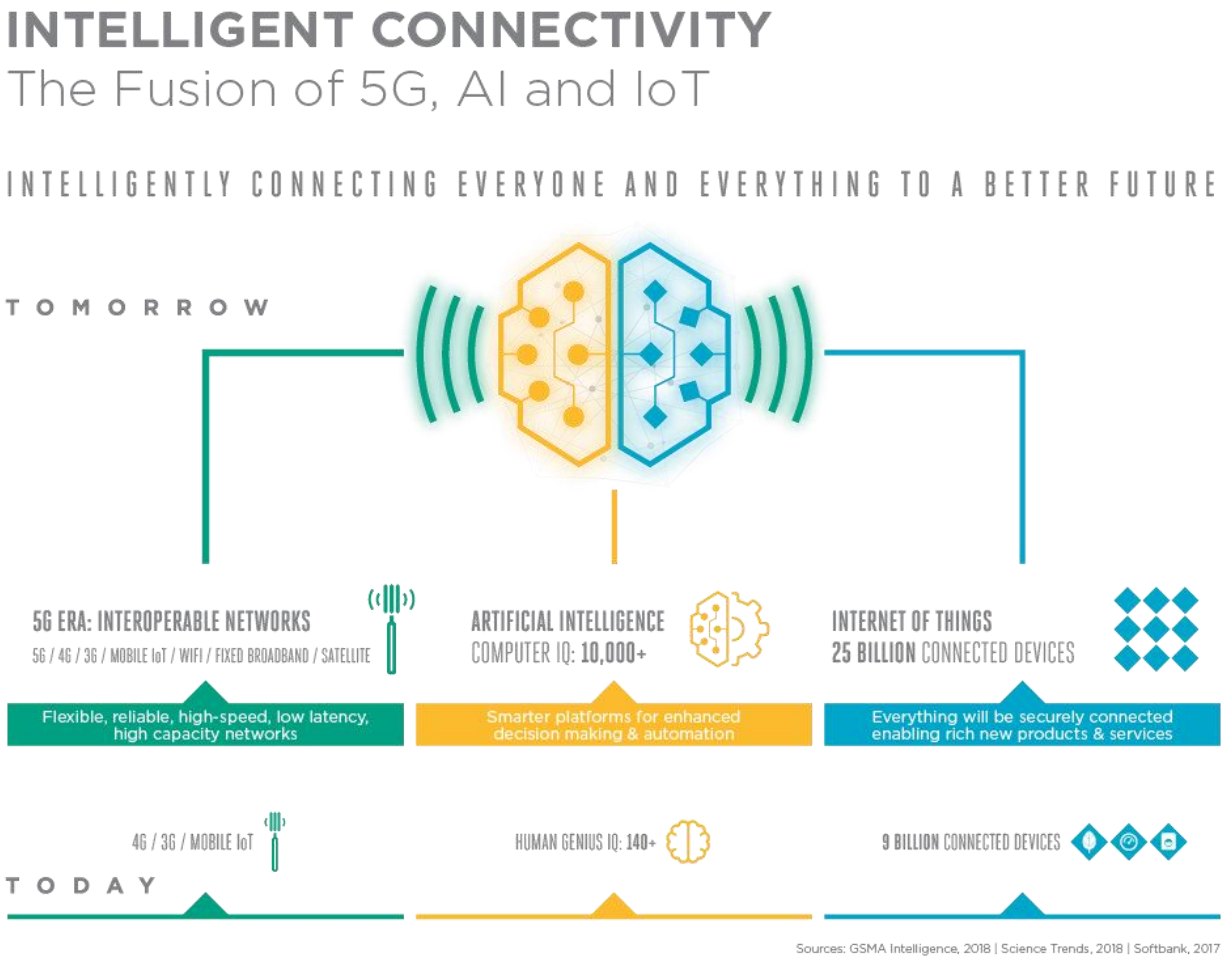
Why Smart Office ?



Smart Office를 위한 기술요소



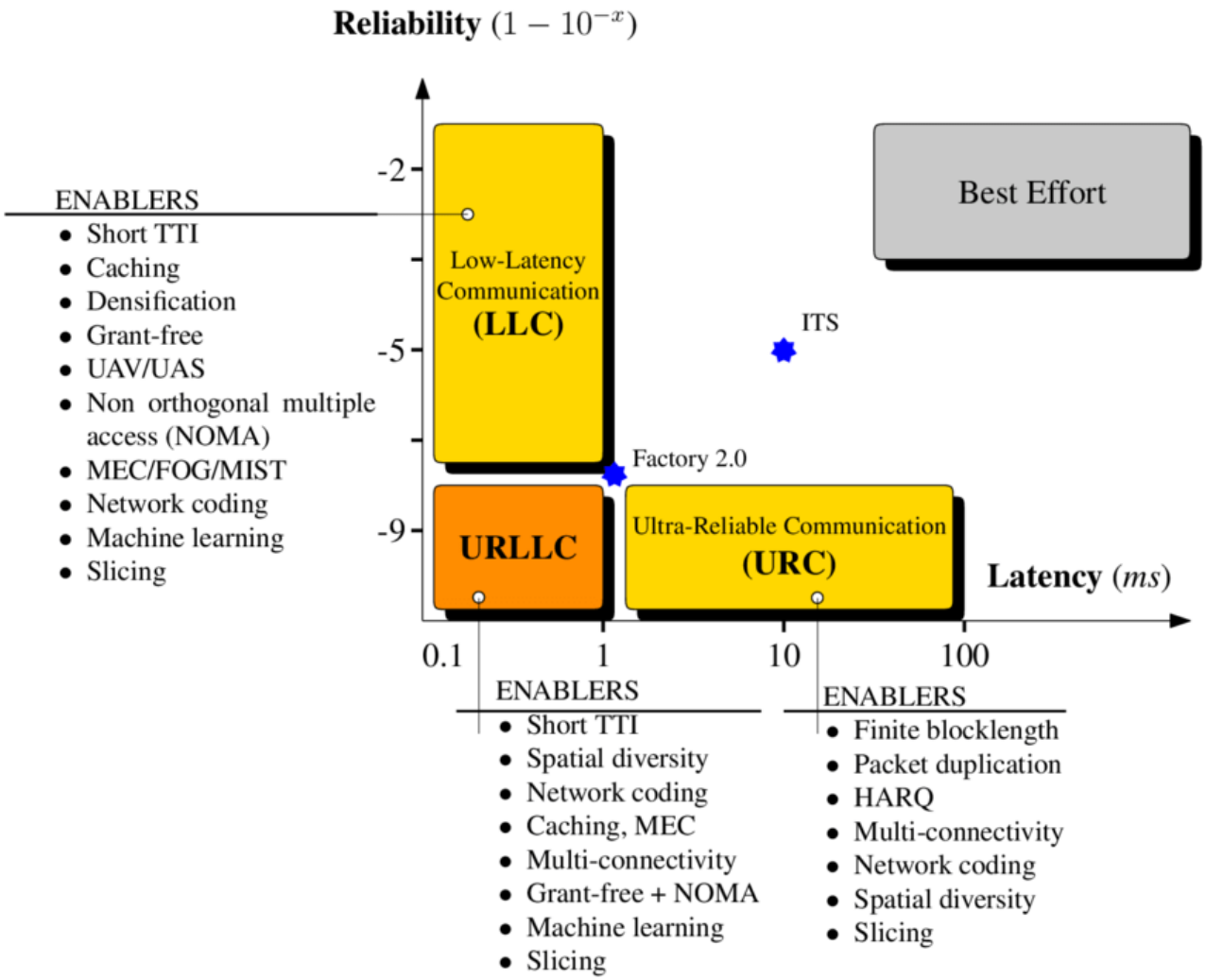
Intelligent Connectivity



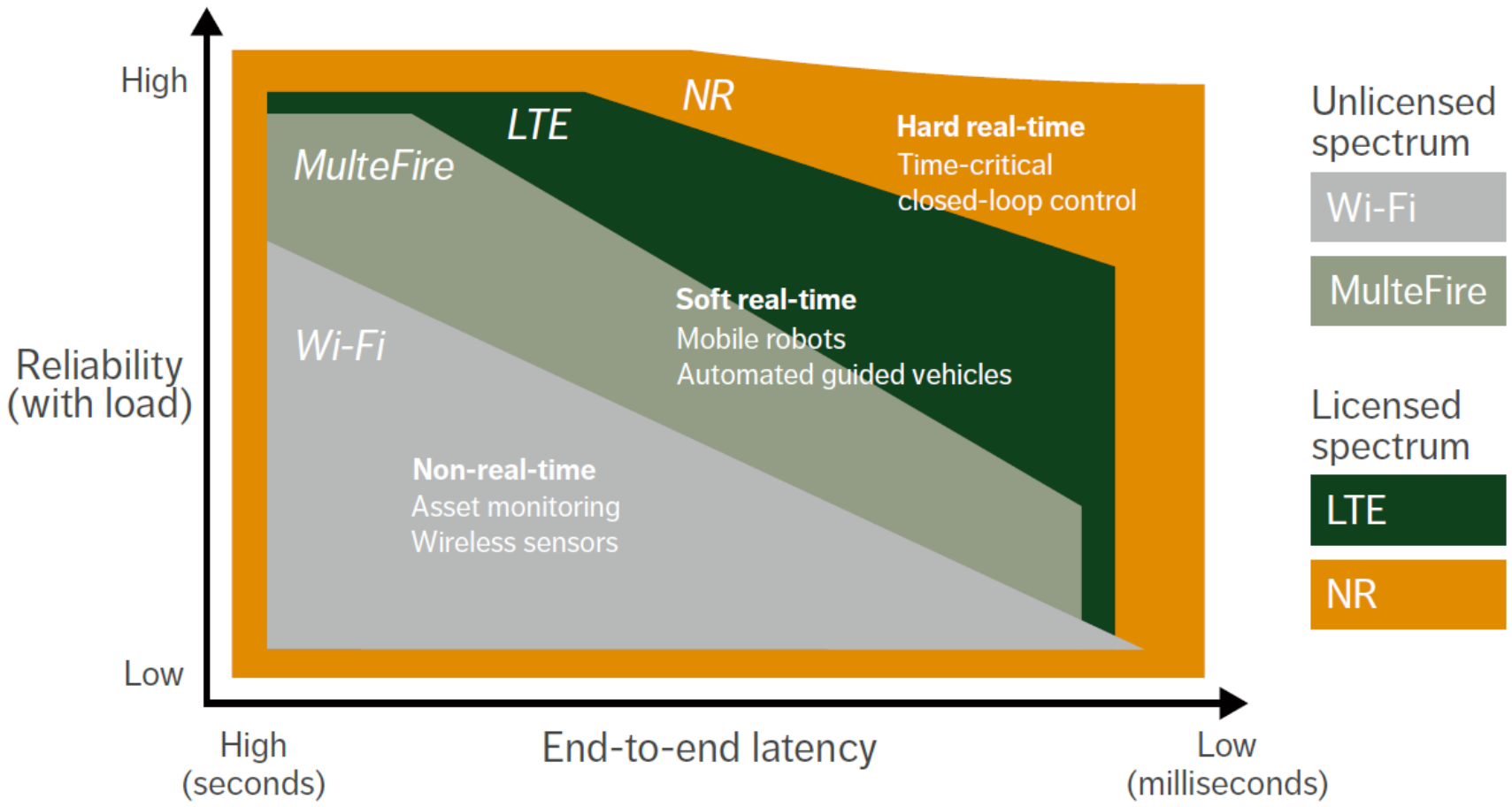
출처: GSMA

URLLC

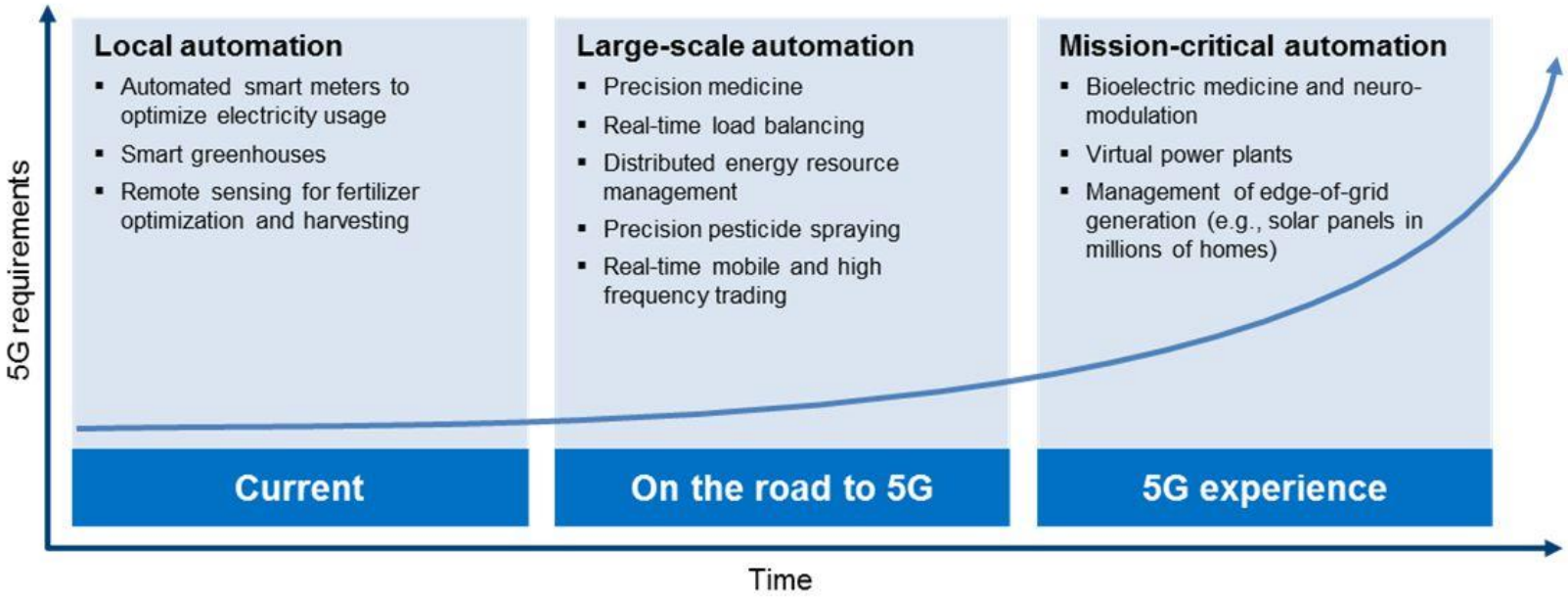
URLLC 정의


Reliability $(1 - 10^{-x})$
-2
-5
-9
ENABLERS
• Short TTI
• Caching
• Densification
• Grant-free
• UAV/UAS
• Non orthogonal multiple access (NOMA)
• MEC/FOG/MIST
• Network coding
• Machine learning
• Slicing
Low-Latency Communication (LLC)
Best Effort
ITS
Factory 2.0
URLLC
Ultra-Reliable Communication (URC)
Latency (ms)
0.1
1
10
100
ENABLERS
• Short TTI
• Spatial diversity
• Network coding
• Caching, MEC
• Multi-connectivity
• Grant-free + NOMA
• Machine learning
• Slicing
ENABLERS
• Finite blocklength
• Packet duplication
• HARQ
• Multi-connectivity
• Network coding
• Spatial diversity
• Slicing

Reliability & Latency



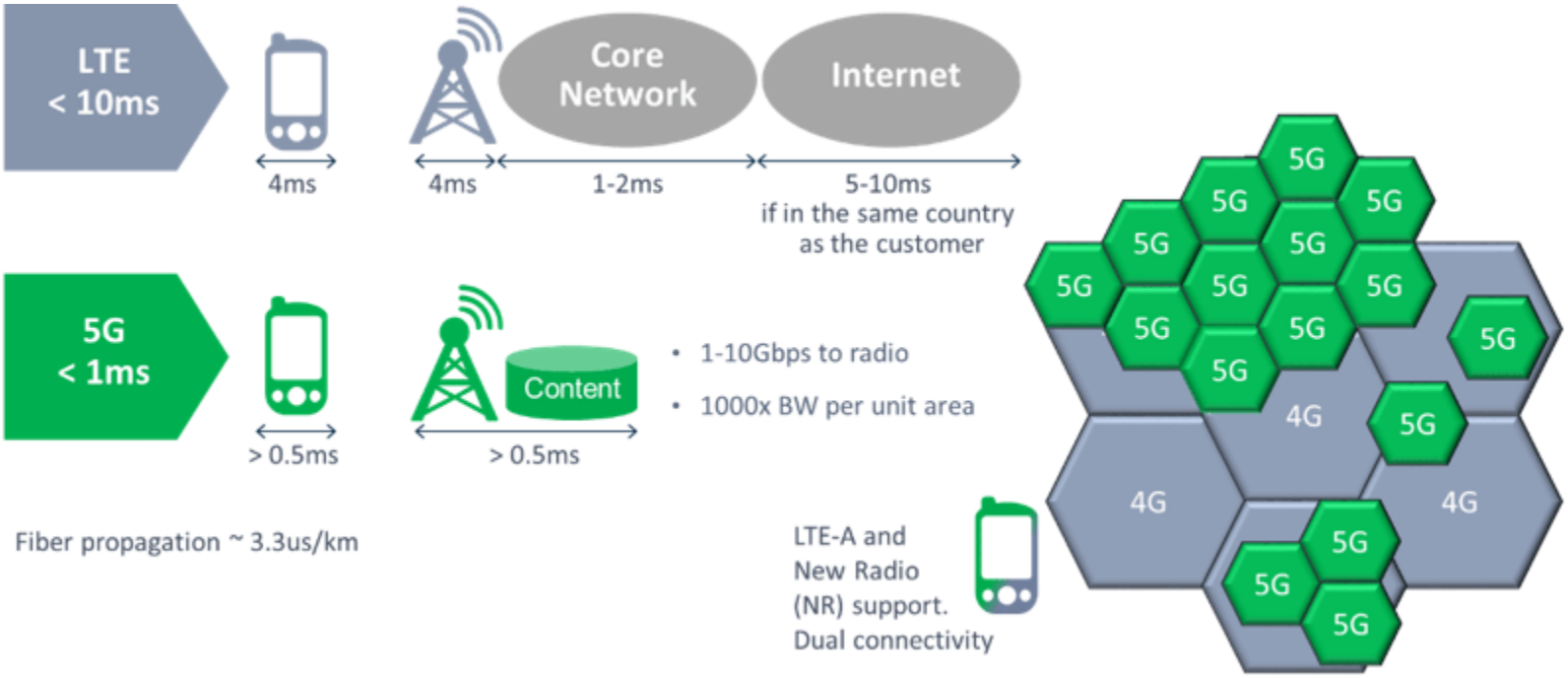
URLLC 서비스 전망



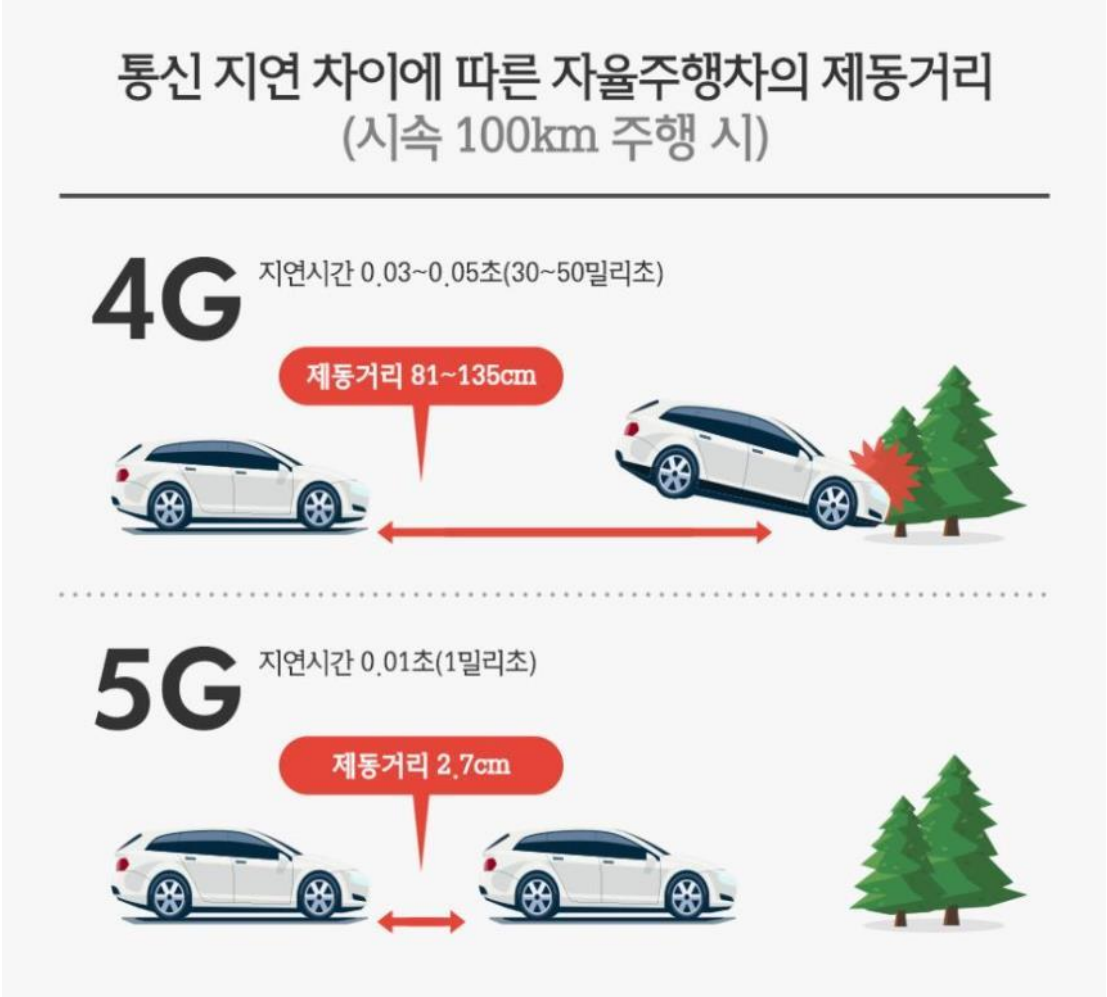
Source: Ericsson and Arthur D. Little analysis

Figure: Evolution of 5G Real-Time Automation Cluster

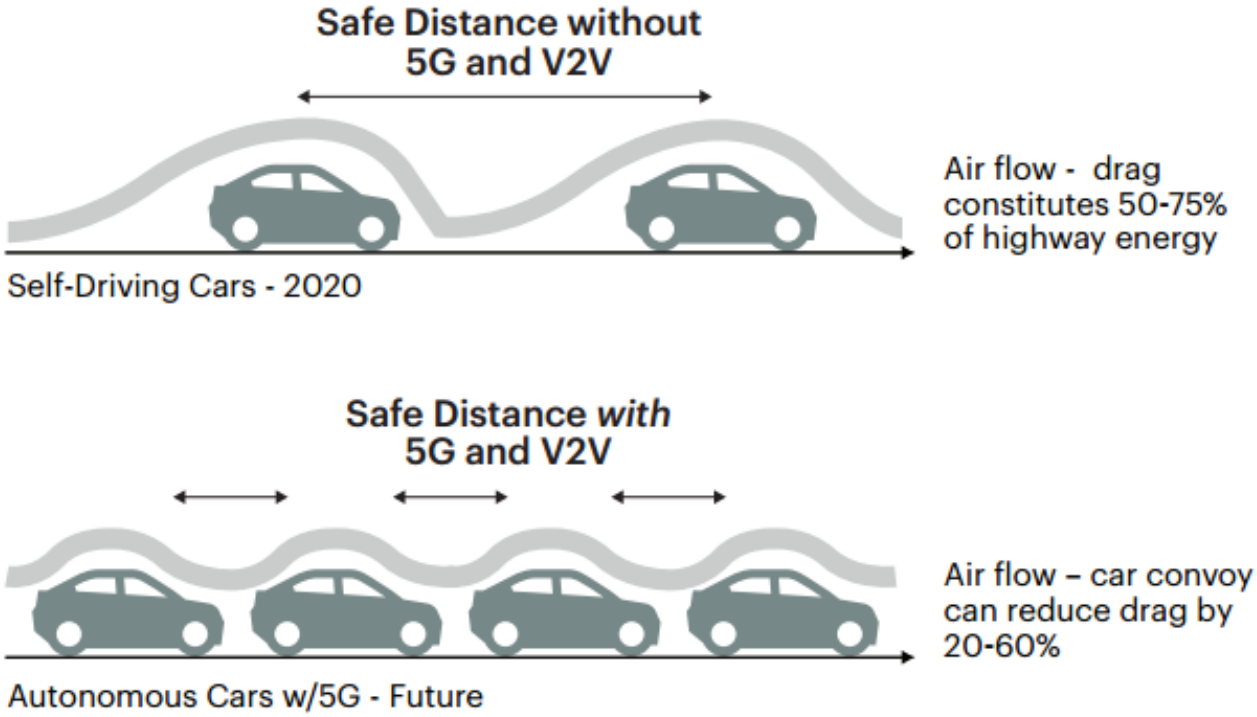
4G, 5G Latency 비교



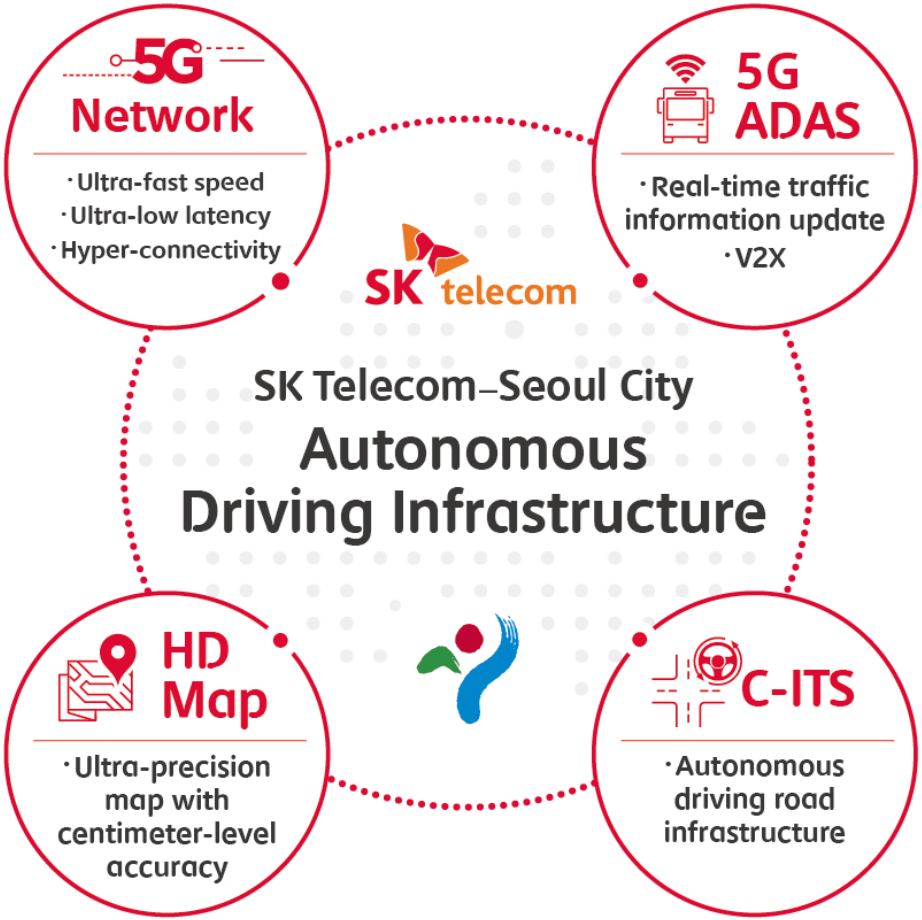
자율주행차 - 제동거리


통신 지연 차이에 따른 자율주행차의 제동거리
(시속 100km 주행 시)
4G
지연시간 0.03~0.05초(30~50밀리초)
제동거리 81~135cm
5G
지연시간 0.01초(1밀리초)
제동거리 2.7cm

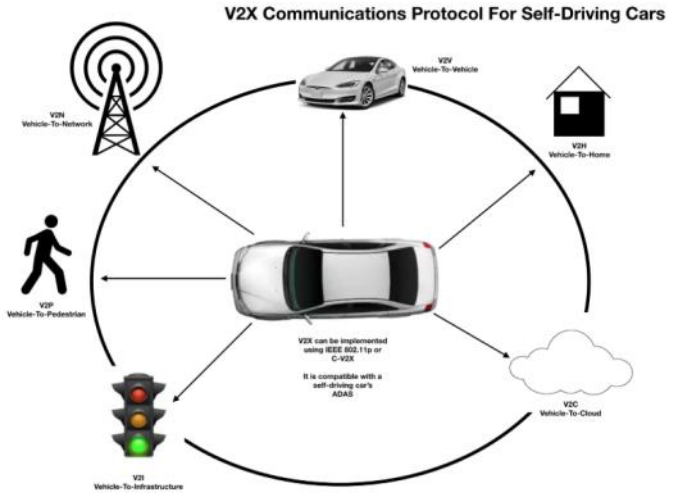
자율주행차 - 군집주행


Safe Distance without
5G and V2V
Air flow - drag
constitutes 50-75%
of highway energy
Self-Driving Cars - 2020
Safe Distance *with*
5G and V2V
Air flow – car convoy
can reduce drag by
20-60%
Autonomous Cars w/5G - Future

자율주행차 요소기술


5G
Network
·Ultra-fast speed
·Ultra-low latency
·Hyper-connectivity
5G
ADAS
·Real-time traffic information update
·V2X
SK telecom
SK Telecom–Seoul City
Autonomous
Driving Infrastructure
HD
Map
·Ultra-precision map with centimeter-level accuracy
C-ITS
·Autonomous driving road infrastructure

3GPP, 5GAA Activities



5GAA Automotive Association

Evolving C-V2X Direct Communications towards 5G NR

While maintaining backward capabilities

Evolution to 5G NR, while being backward compatible
C-V2X Rel-14 is necessary and operates with Rel-16

Basic safety
IEEE 802.11p

Basic and enhanced safety
C-V2X Rel-14/Rel-15 with enhanced range and reliability

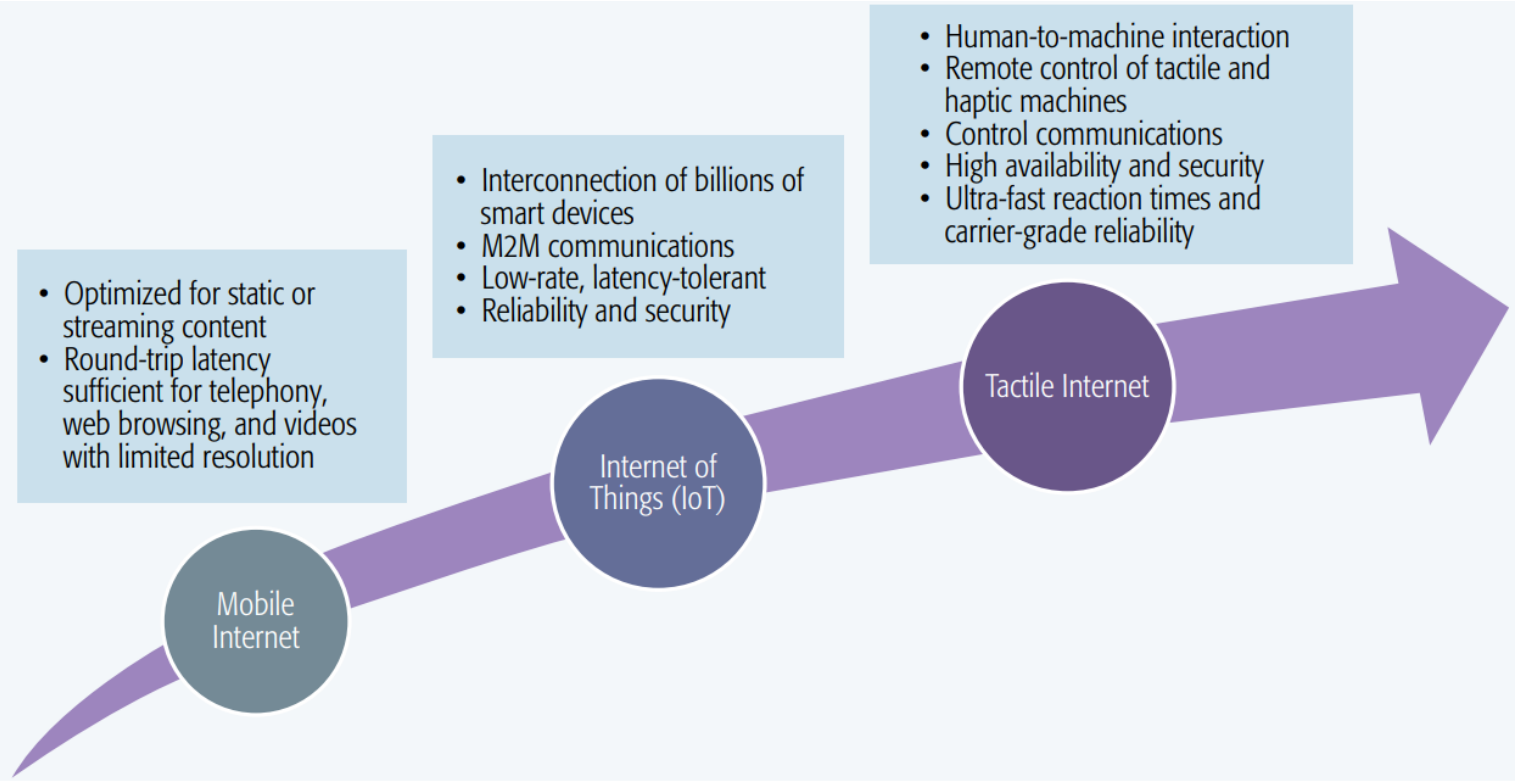
Autonomous driving use cases
5G NR C-V2X Rel-16

Backward compatible with Rel-14/Rel-15 enabled vehicles

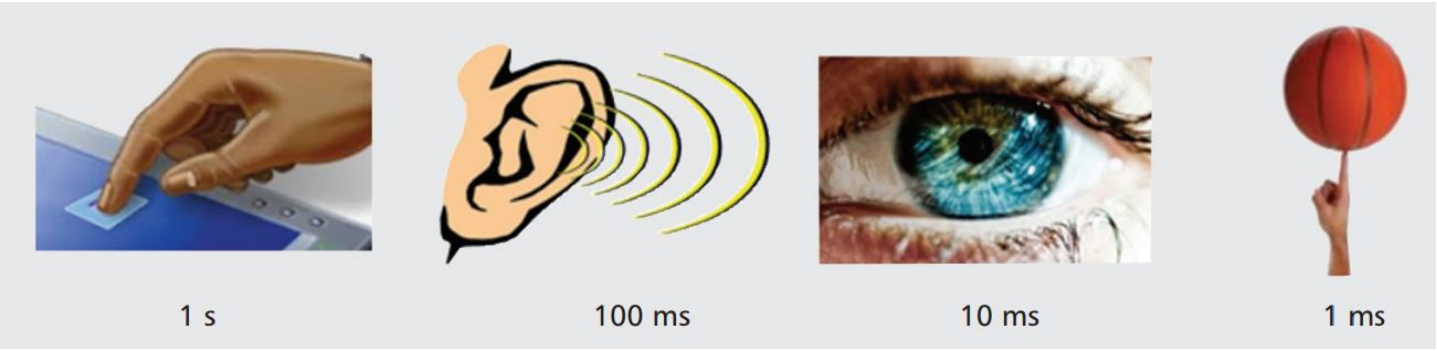
Higher throughput
Higher reliability
Wideband carrier support
Lower latency

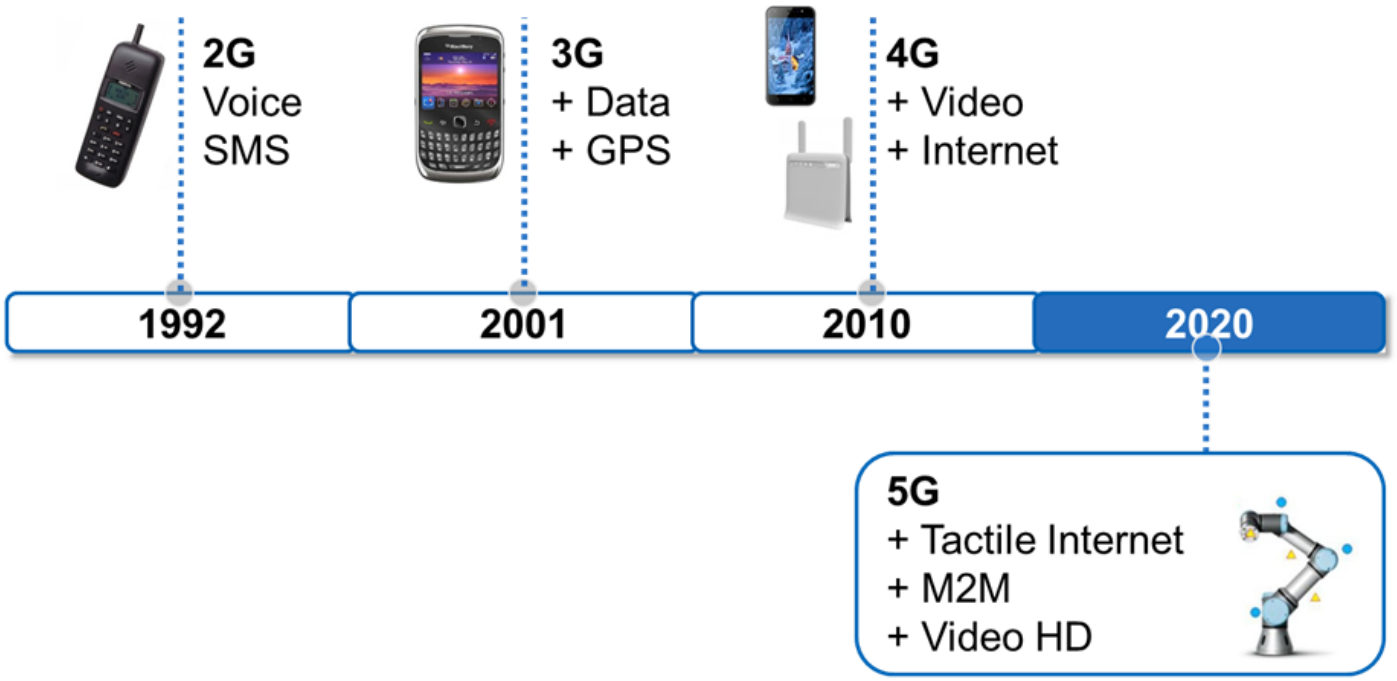
5

Mobile Internet, IoT, Tactile Internet



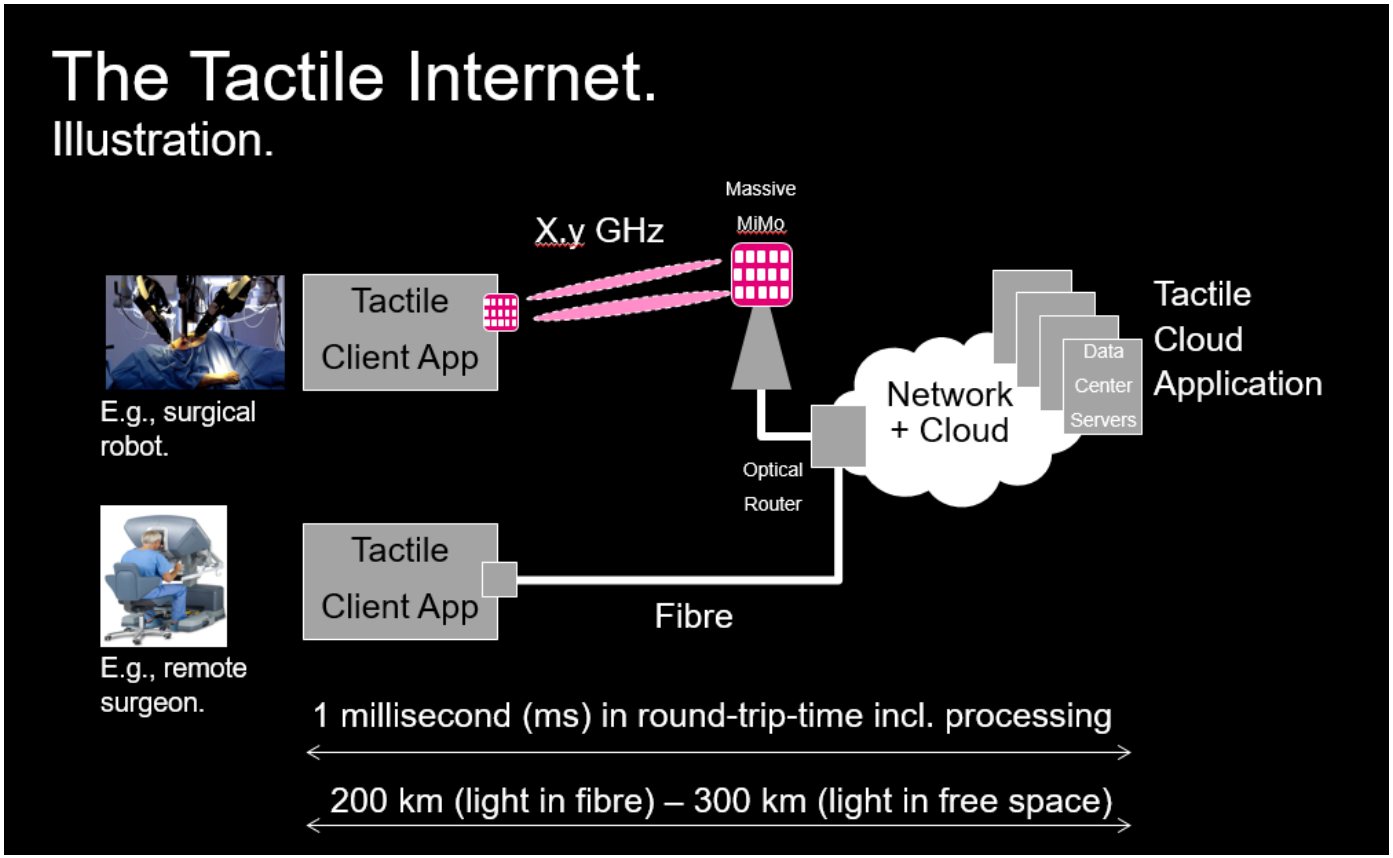
사람 감각의 반응시간, Tactile Internet





Tactile Internet(1)

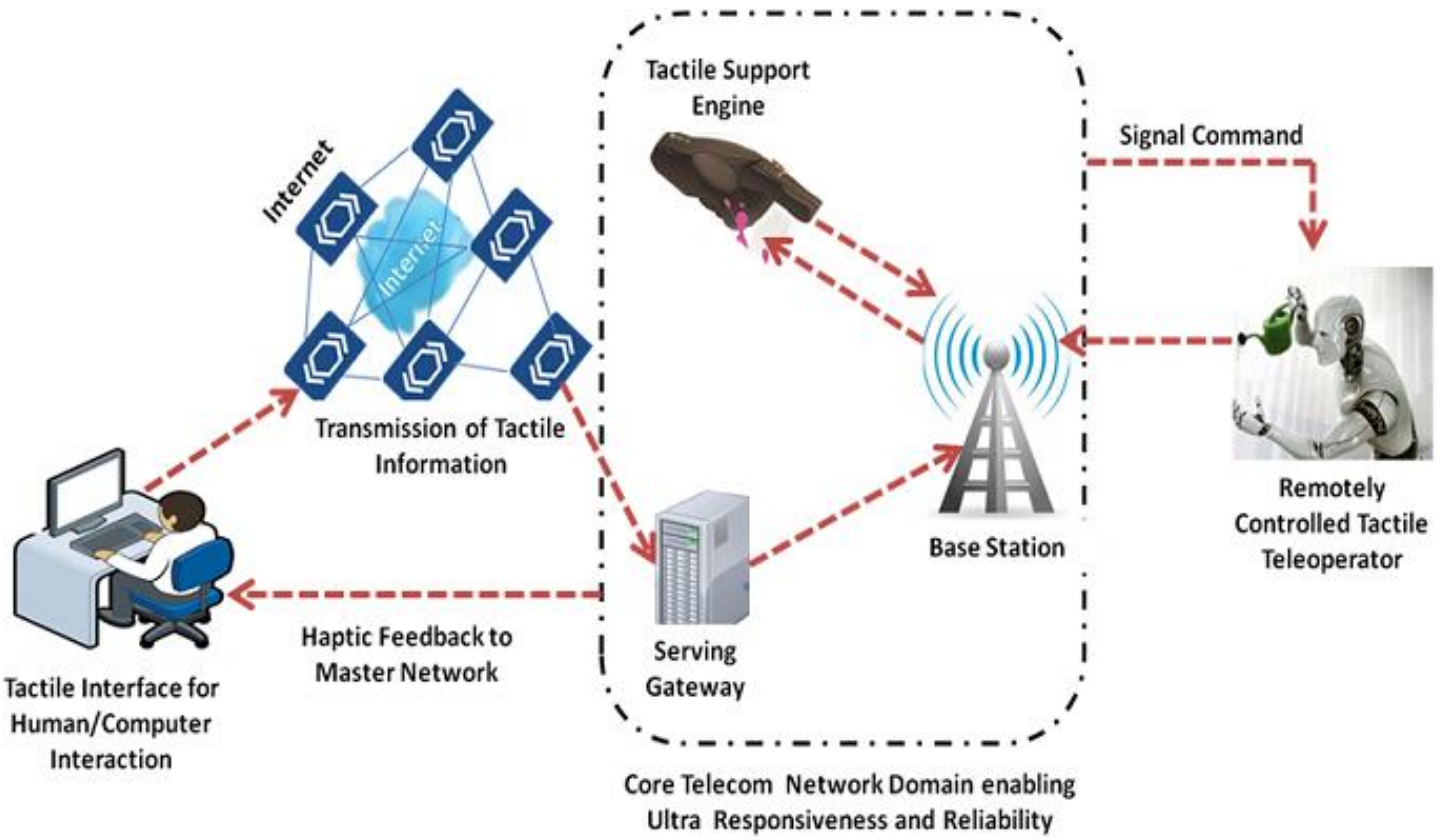
eMBB + URLLC + mMTC



- Tactile Internet: 인터넷을 촉감(Tactile) 정보를 송수신하는 서비스
  - 5G의 초저지연, 초고속 통신으로 제공 가능
- 원격수술 예: 의사가 수술상황을 손으로 느끼면서 수술 가능

Tactile Internet(2)

eMBB + URLLC + mMTC



- Tactile Internet 서비스를 제공하기 위한 Platform 사업이 유망함(2~3년 뒤)
  - Game, Entertainment, Factory, Retail 등에 적용 가능
- Tactile Internet Platform은 MEC와 연계됨

5G 이동통신 주요기술(1)

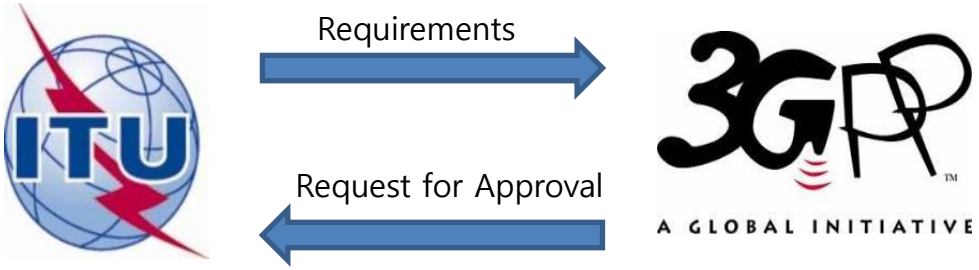
Hyun-Wook Kim

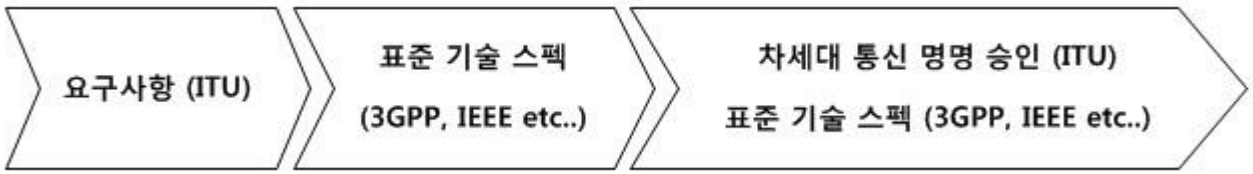
hw.kim@sk.com
hwkim7@gmail.com

목차

표준화

5G 표준화 절차



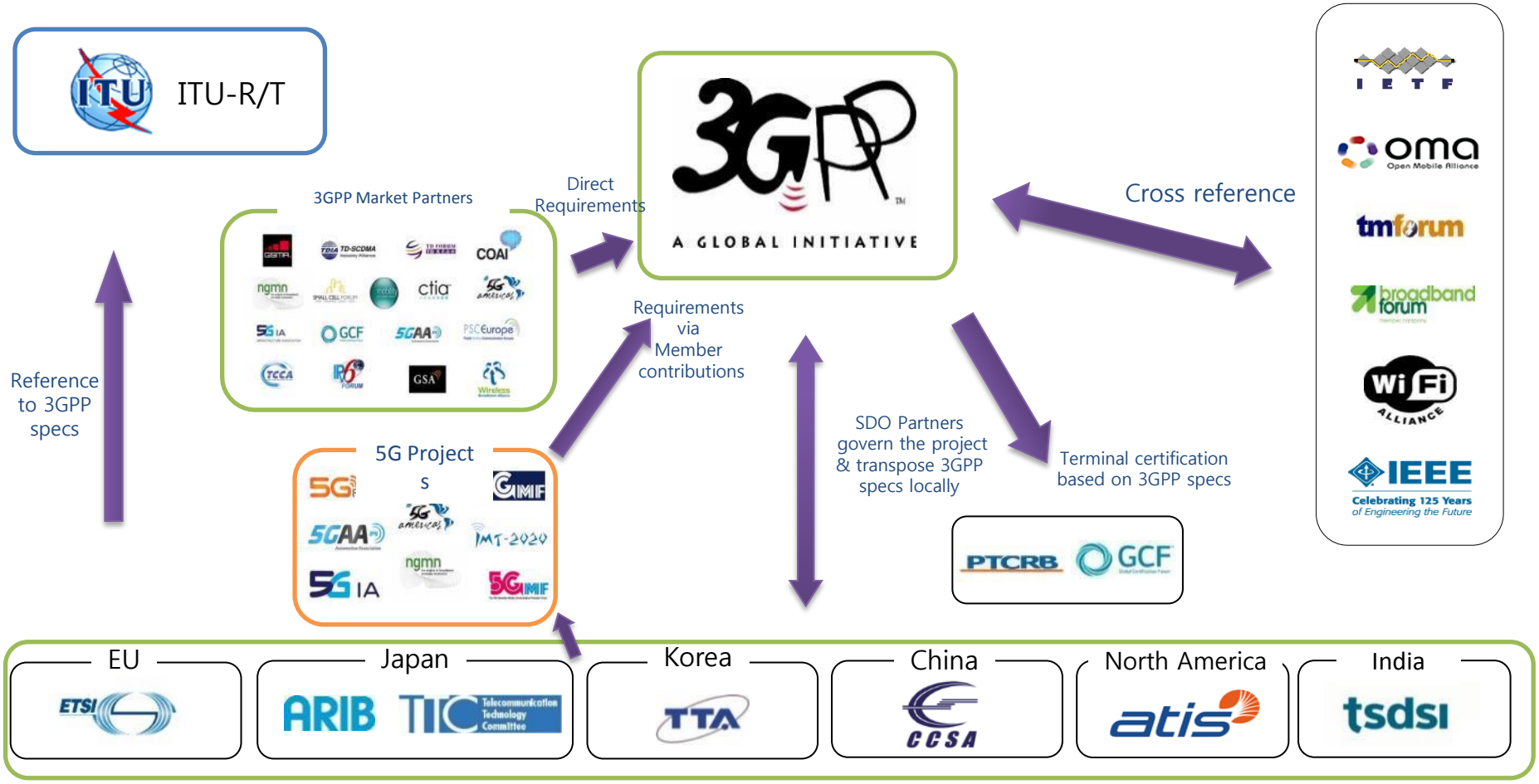


IMT-2020 5G 5G NR

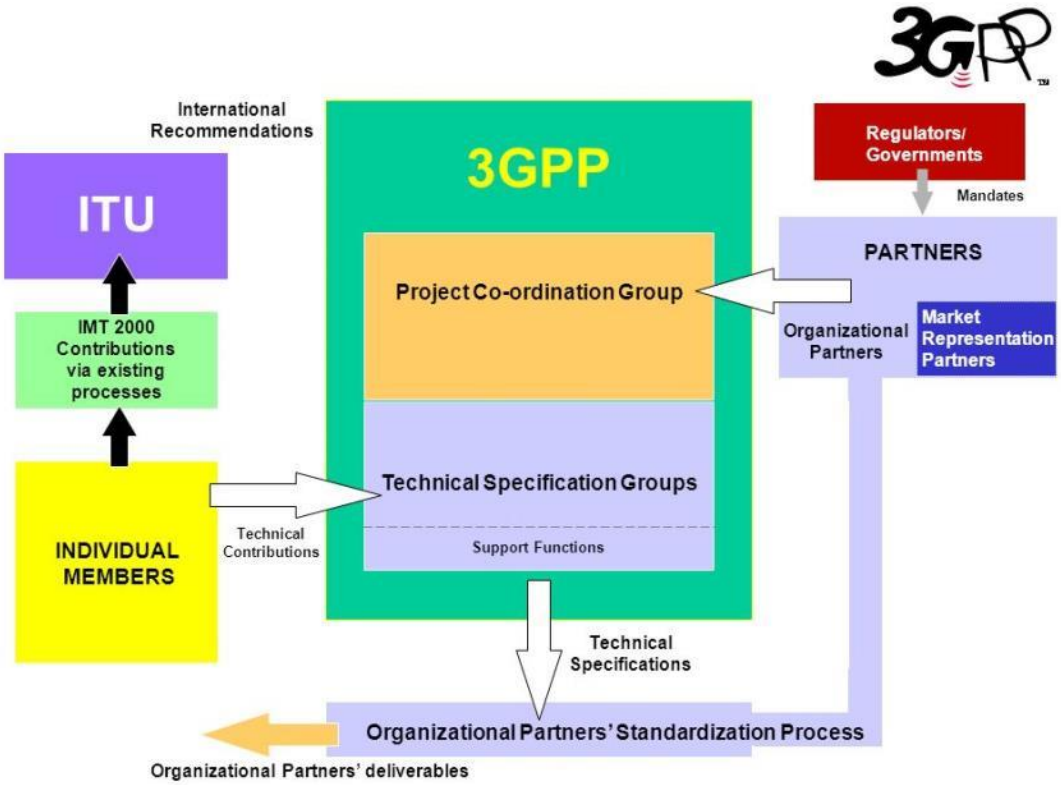
- ITU: UN의 산하기관으로 전세계 통신규격, 규제 등 총괄
- 3GPP: 이동통신 기술규격을 정의하는 전세계 유일한 단체
- 5G의 국제적인 공식명칭은 IMT-2020
- 5G는 일반인의 쉬운 이해를 위한 용어
- NR은 기술적 관점에서 3GPP에서 정의한 용어
- 5G = IMT-2020 = NR, 모두 같은 의미

- ITU: International Telecommunication Union
- 3GPP: 3rd Generation Partnership Project
- IMT: International Mobile Telecommunications

3GPP Eco System



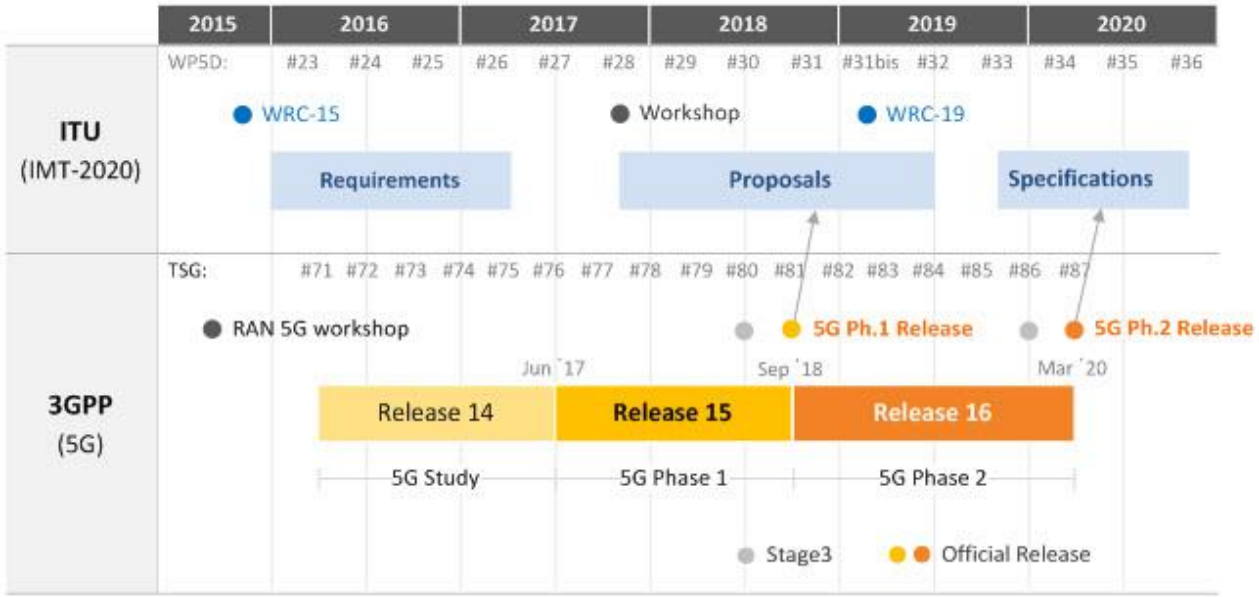
3GPP 표준화 절차



- 3GPP는 ITU의 요구사항에 맞게 기술 규격 정의
  - 외부의 관련 기관, 단체 등으로 부터 의견 수렴
- 3GPP에서 완료된 규격은 최종으로 ITU에서 승인
- 3GPP의 주요 멤버는 칩, 통신장비, 단말기 제조사와 이동통신 사업자임
  - Ericsson, Nokia, 삼성, LG, Qualcomm, Apple 등

- 해당 규격에 특정회사 특허가 규격에 반영될 수 있음
  - 특허괴물 등장(예, InterDigital)

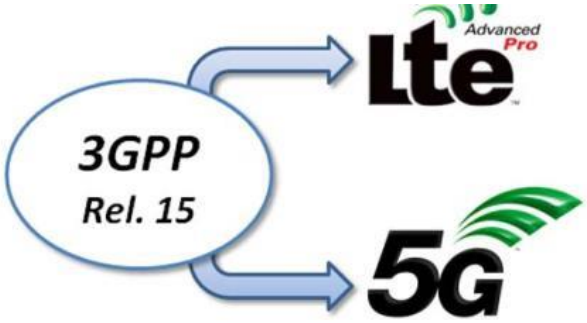
ITU, 3GPP 기술 표준화 일정



- 5G일정은 2020년에 기술개발을 완료하겠다는 계획이었음
  - 즉, 2020년에 상용화가 계획이 아님
- 하지만 미국, 중국, 한국 등에서 Technical Leadership을 확보하기 위하여 경쟁적으로 기술개발과 상용화 추진
- 이러한 요구에 따라 3GPP는 2018년 9월에 상용버전 배포
  - 이 규격을 5G Phase 1(1단계 5G 규격)이라고 함

- 5G Phase 2 규격(Release 16)은 2020년 초 완료 예정
- 3GPP의 Release는 규격 일련번호임
  - Release 97, 98, 99 이후, Release 4, 5, 6 ~ 17
- Release는 단순 일련번호이고, 각 Release별 큰 기술적 변경이 있을 수 있음

5G 표준화 과정



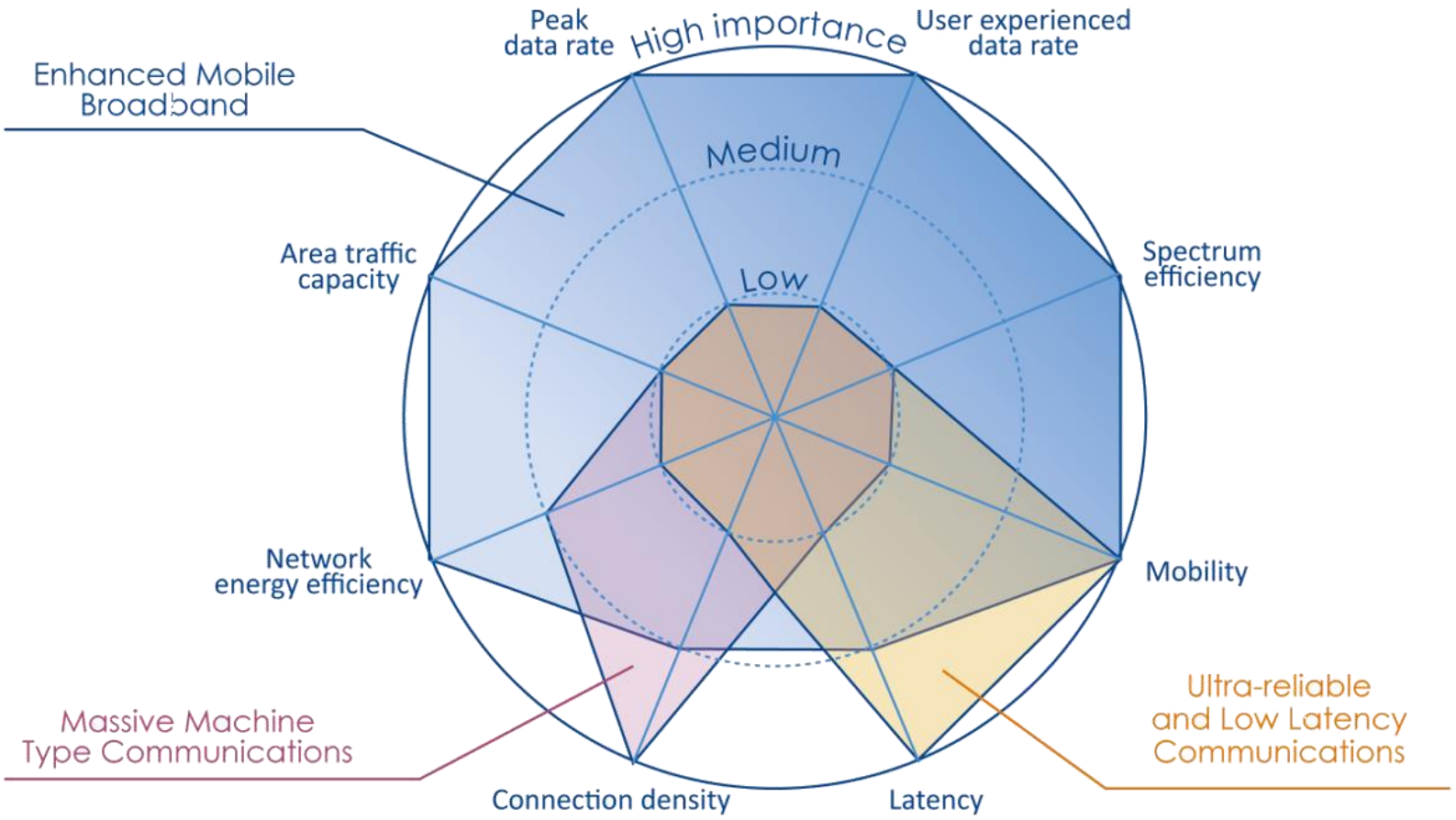
Phase 1 – mid 2018

- Focus on **eMBB** and low latency aspects
- **Minimized changes to core architecture** (LTE-EPC) – **NSA** operation initially
- 5G RAT - focus on “conventional” frequency channels

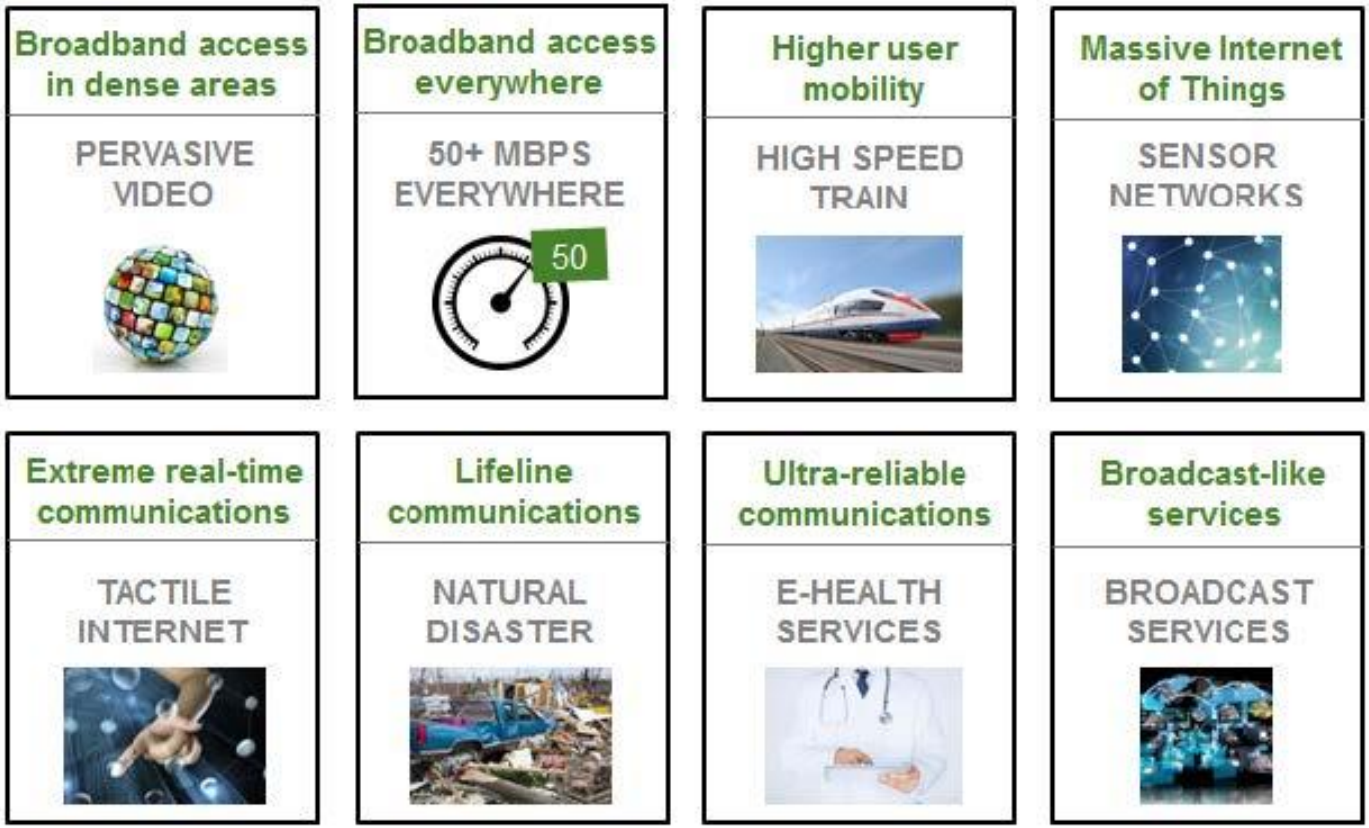
Phase 2 – mid 2020

- Focus on **mMTC** and **URLLC**
- Novel layers and architecture to allow full 5G potential (vehicular and multicast services)
- “mmWave” 28, 37, 39 GHz channels and unlicensed spectrum

ITU, IMT-2020 요구사항



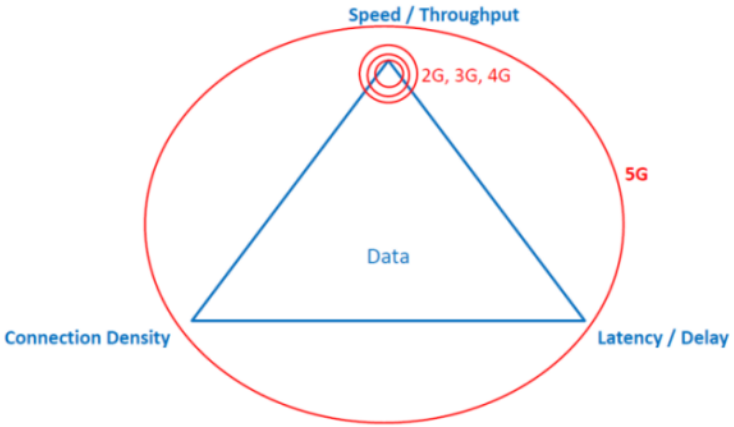
NGMN, 5G Service Use Cases(2015년)

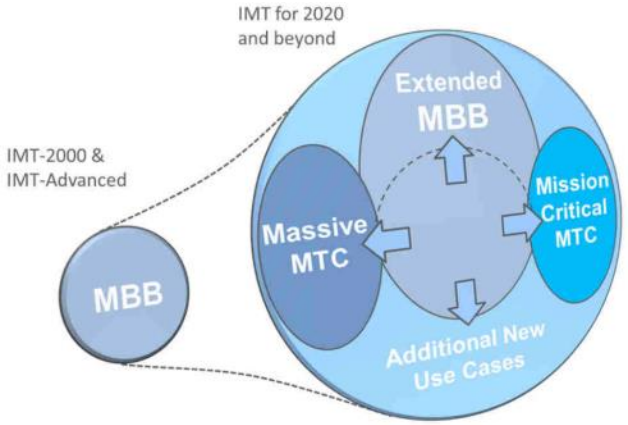


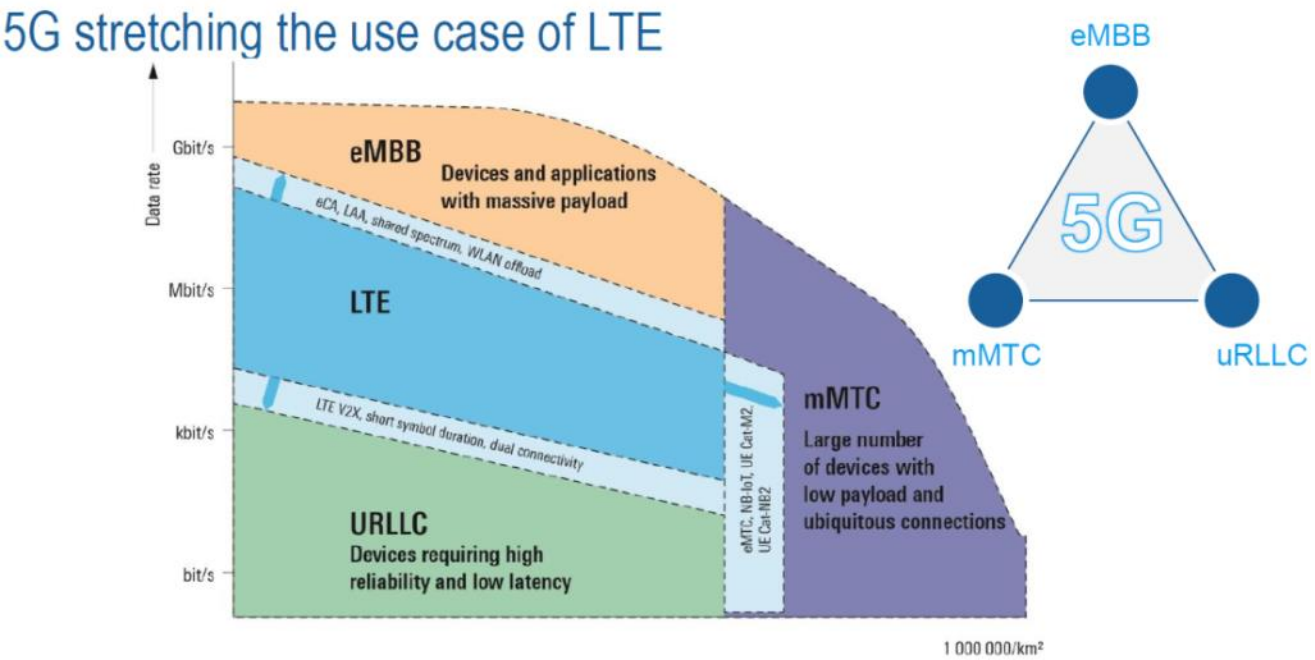
- ITU에서 IMT-2020 요구사항 배포 이전에 NMGN 등에서 Use Cases를 받음
- NMGN은 5G Use Cases를 초고속 통신, 초연결성, 초저지연 등으로 서비스 제안

* NGMN: Next Generation Mobile Networks

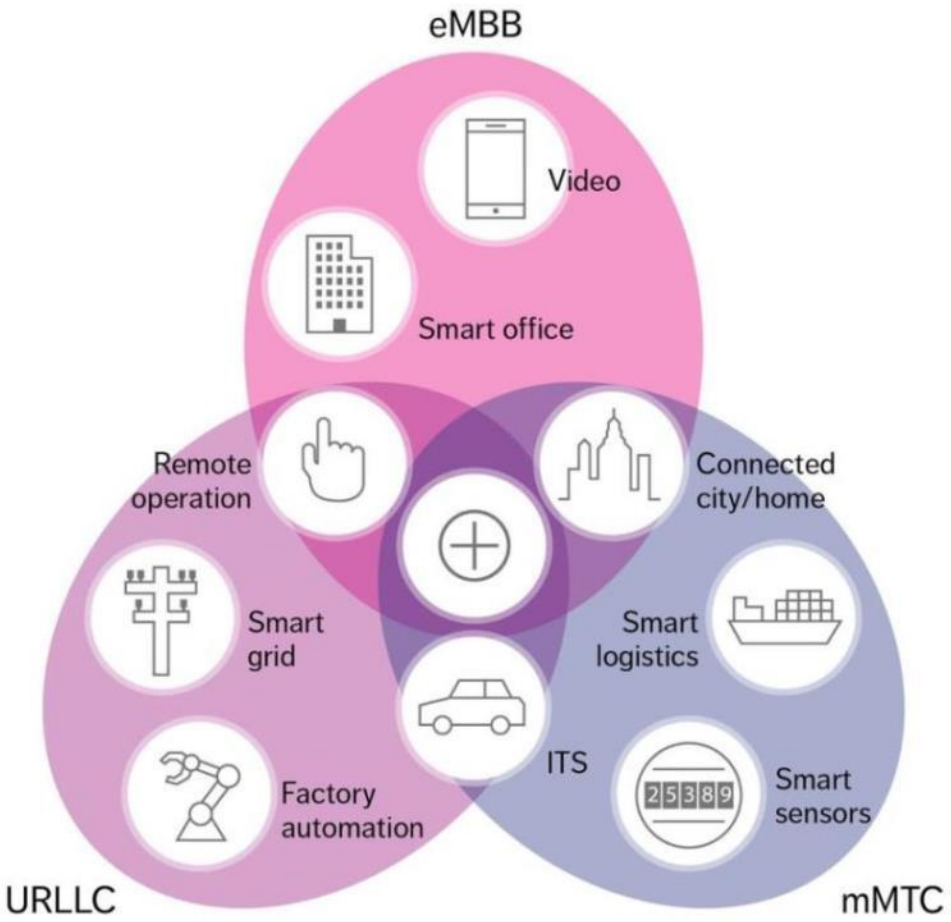
4G 대비 5G 표준 방향성







ITU, 주요 서비스

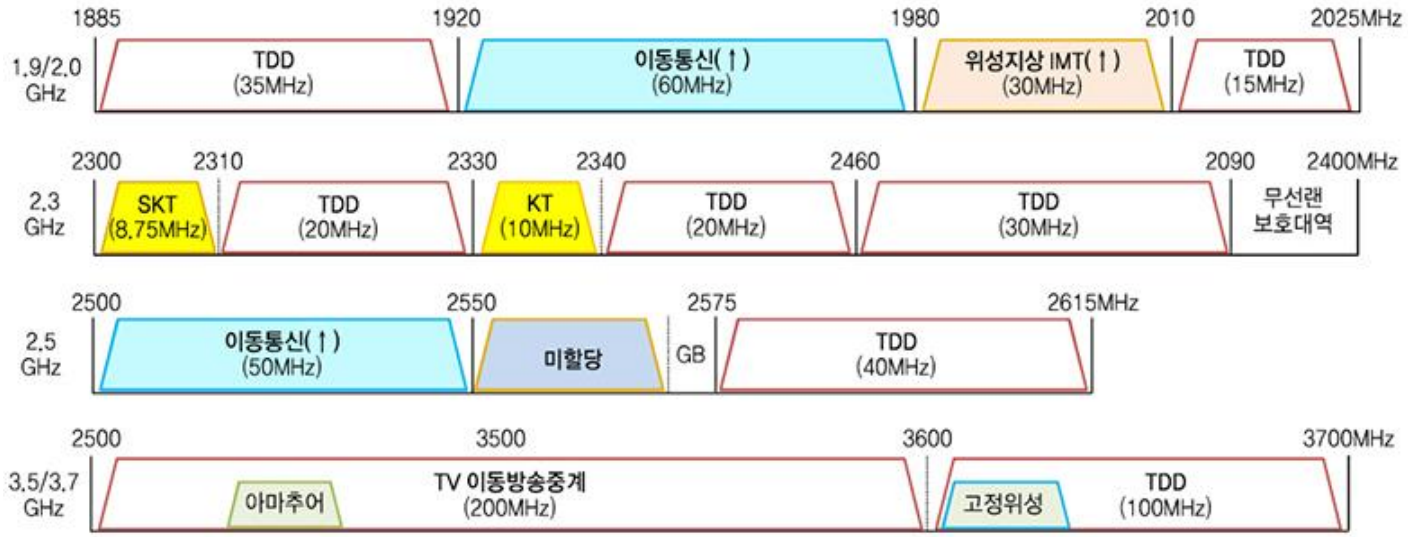


- 5G 대부분 서비스는 eMBB, mMTC, URLLC가 융합되어 제공됨

* eMBB: enhanced Mobile Broadband
* mMTC: massive Machine Type Communication
* URLLC: Ultra Reliable Low Latency

주파수

5G 주파수 할당 배경

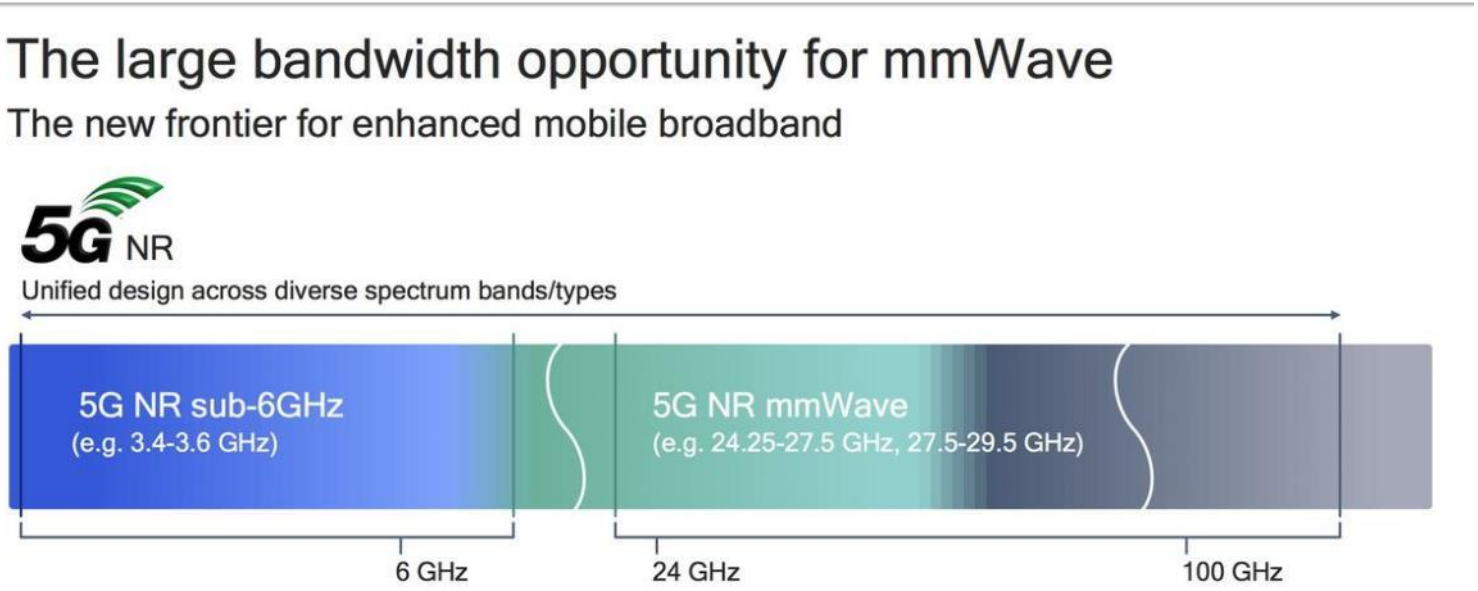


- 5G가 4G 대비 가장 큰 기술적인 차이점은 주파수 대역과 주파수 폭
- 대부분 국가는 이동통신에 적합한 700MHz ~ 3GHz 사이 여유 주파수가 없음
  - 즉, 이 대역은 다른 목적으로 이미 사용 중, 5G로 할당할 수 없음

- ITU 산하 주파수 관련 단체인 WRC는 5G 목적으로 새로운 주파수 대역 할당
  - 크게 6GHz 이하와 6GHz 이상(mmWave)으로 정의
  - 3.5GHz 대역은 미국의 CBRS에서 유래

* CBRS: Citizens Broadband Radio Service

5G 주파수 세부 현황

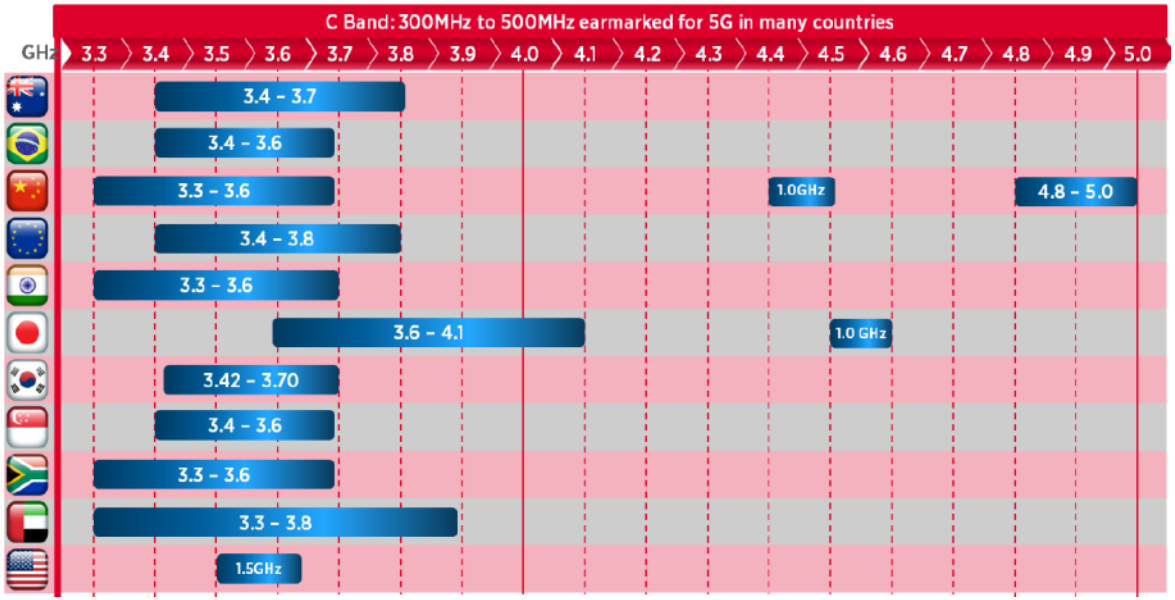


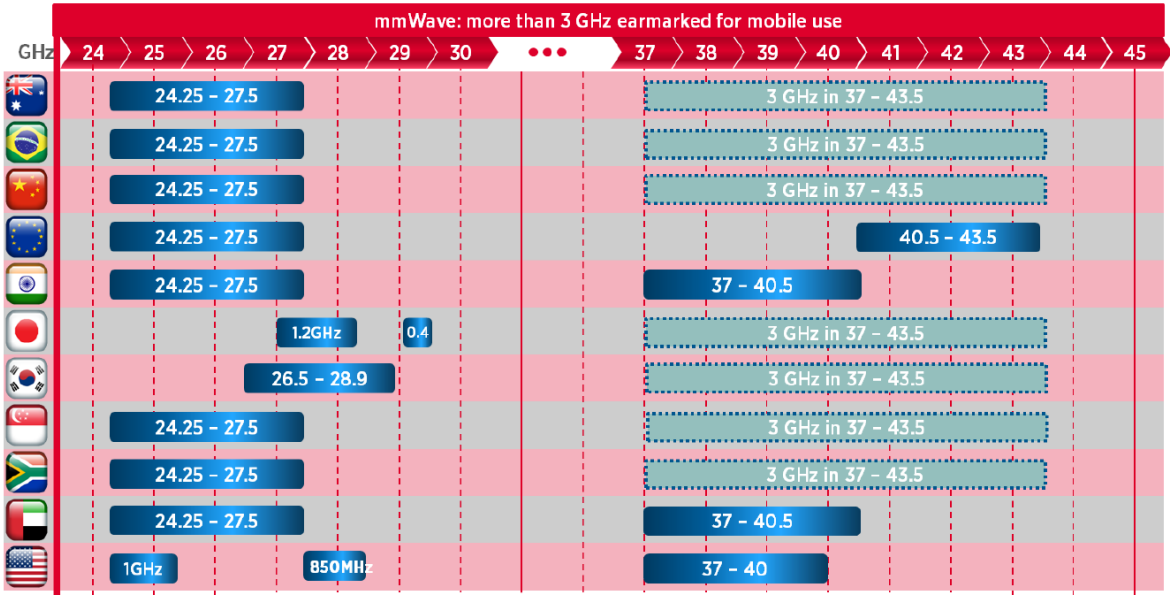
- 5G가 기존대비 가장 큰 차이점은 새로운 주파수 대역(New Radio)를 사용하는 것임
  - 새로운 주파수 대역에 주파수 폭을 광대역으로 사용

- 5G 주파수는 크게 6GHz를 중심으로 Below 6GHz와 Above 6GHz로 구분
  - Above 6GHz 주파수에서 24GHz 이상을 mmWave(milimeter Wave)라고 함

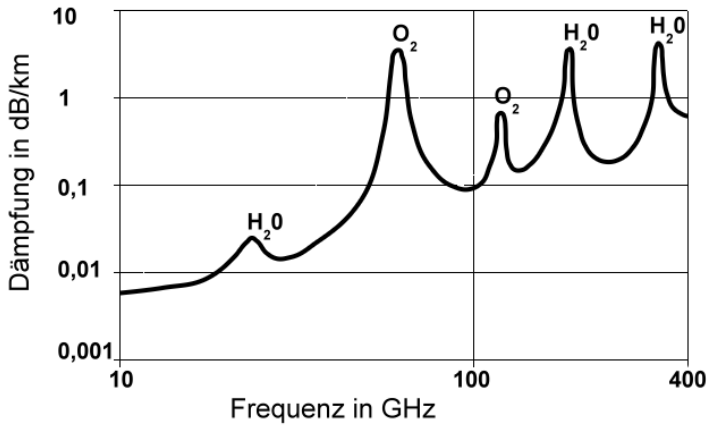
- 기존의 GSM, UMTS, LTE 등의 주파수 대역에도 5G 서비스 가능

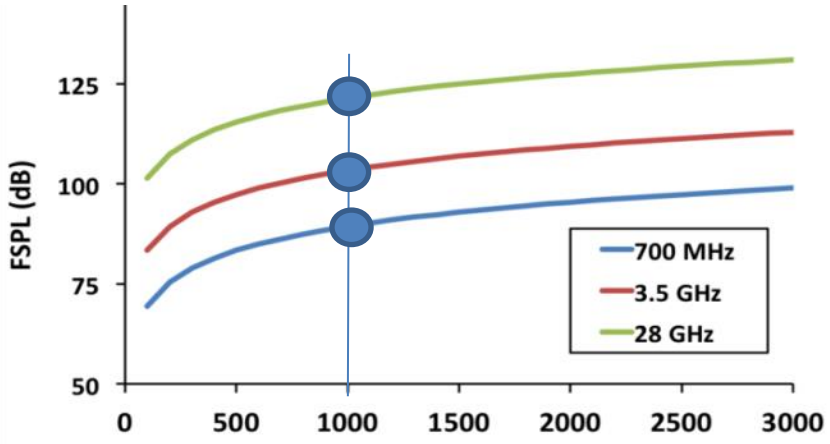
5G 주파수 할당 현황(Global)



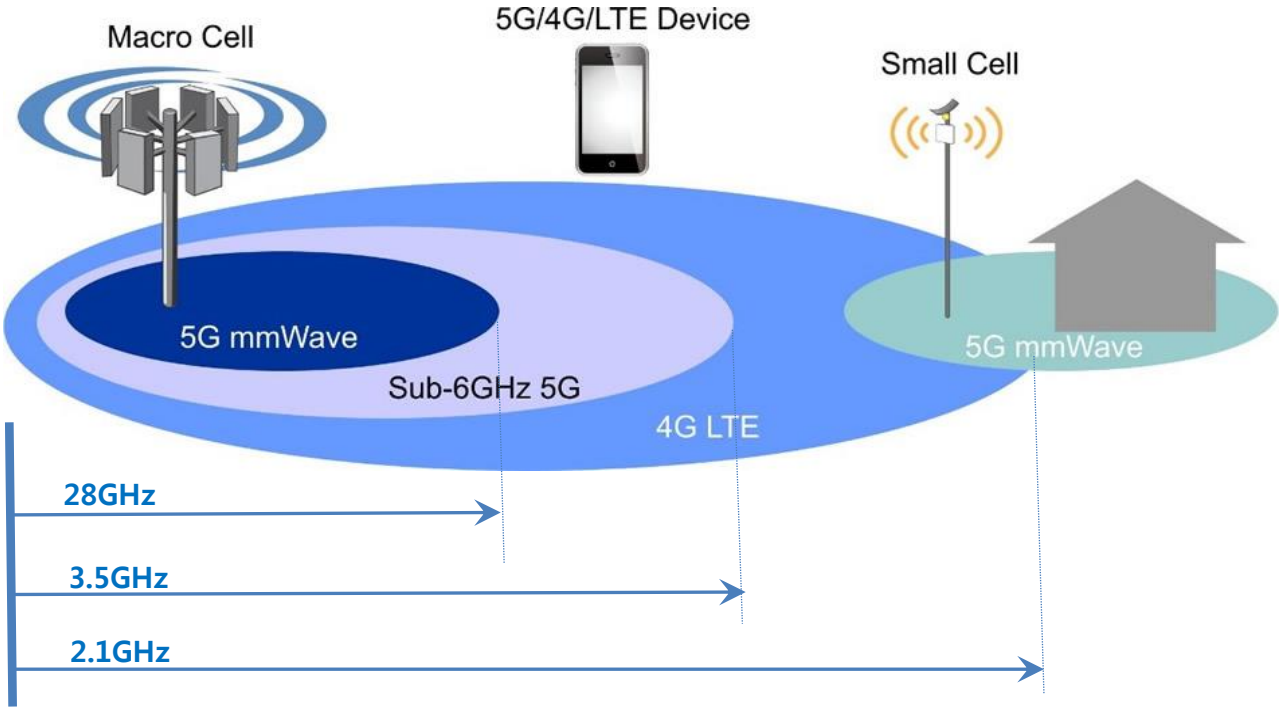


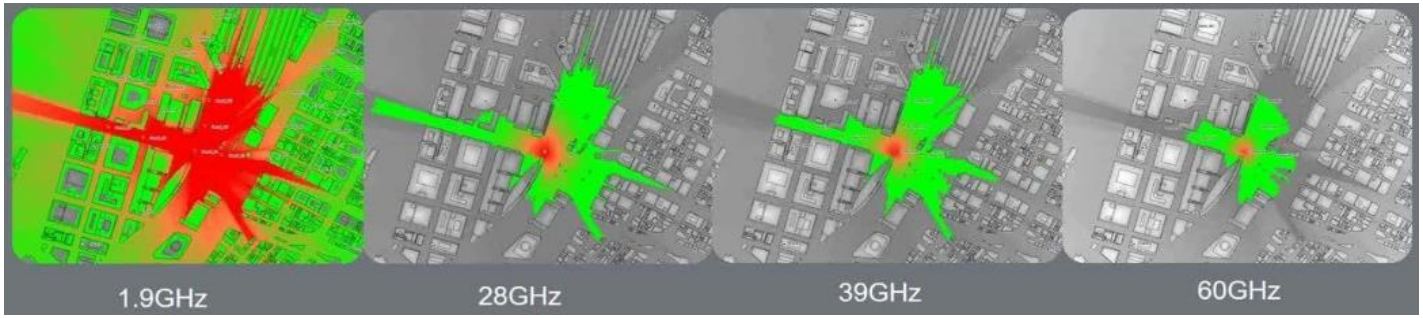
주파수 대역 별 특징


Dämpfung in dB/km
10
1
0,1
0,01
0,001
H_20
O_2
O_2
H_20
H_20
10
100
400
Frequenz in GHz


FSPL (dB)
125
100
75
50
0
500
1000
1500
2000
2500
3000
700 MHz
3.5 GHz
28 GHz

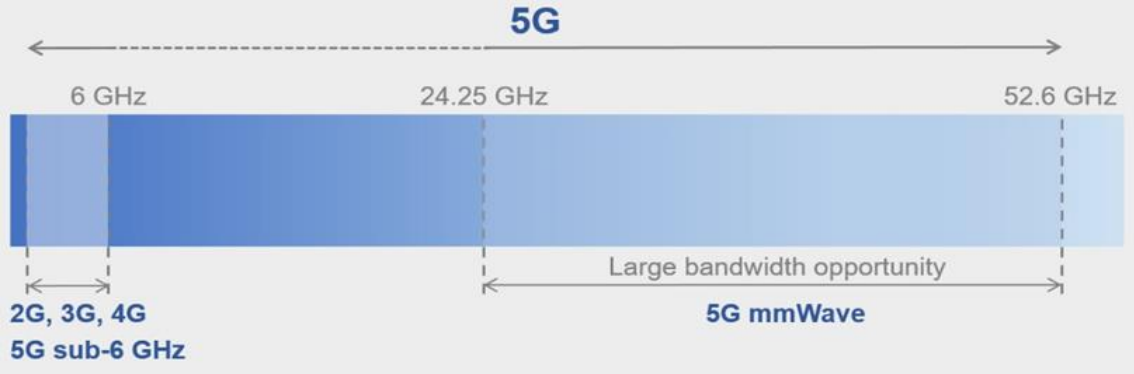
5G mmWave Propagation 특성





국내 5G 주파수 대역

국제 표준 주파수



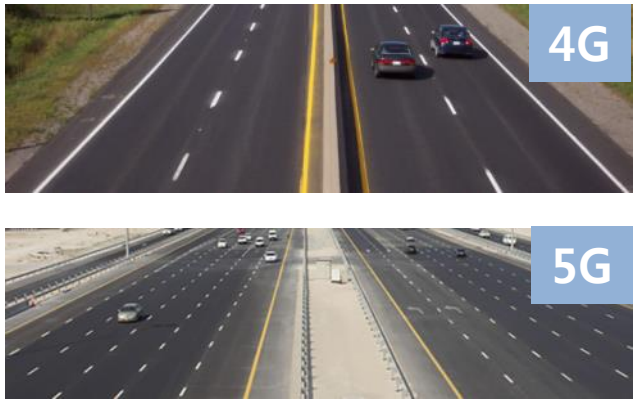
할당 받은 주파수

5G 주파수 경매 결과 (단위: 원)

대역	3.5GHz			28GHz		
이통사	SKT	KT	LGU+	SKT	KT	LGU+
할당폭(㎒)	100	100	80	800	800	800

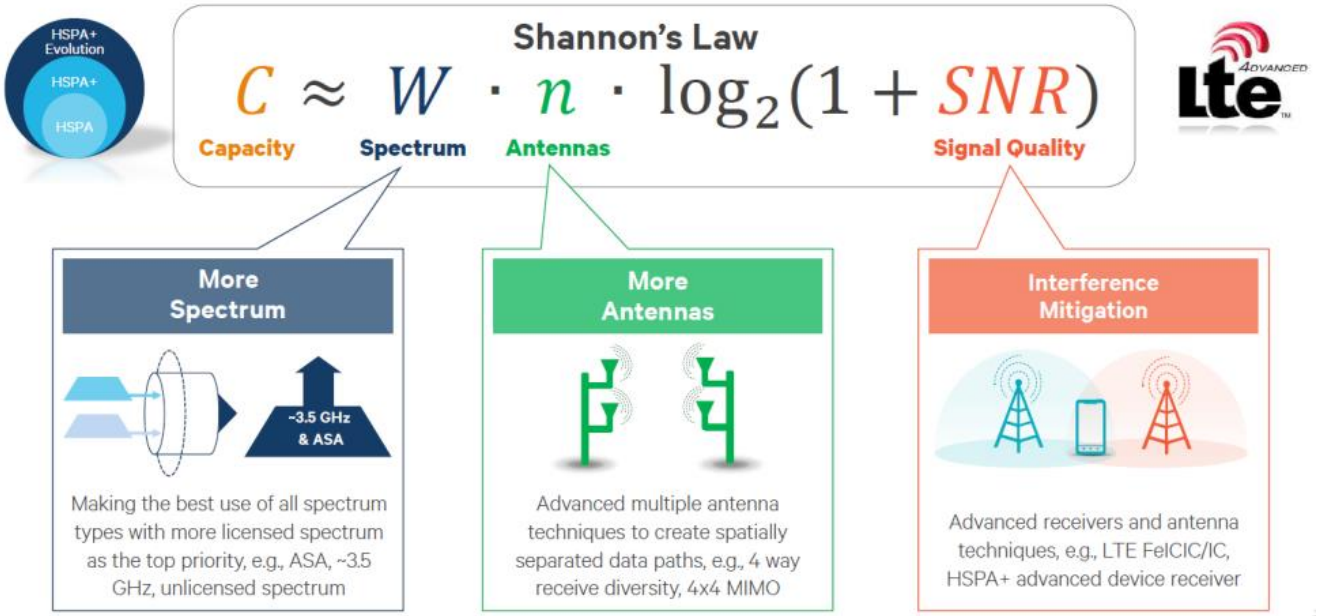
보유중인 총 주파수 폭

	SK텔레콤	KT	LG유플러스
보유량(㎒)	165	125	120
보유 비중(%)	40	30	29

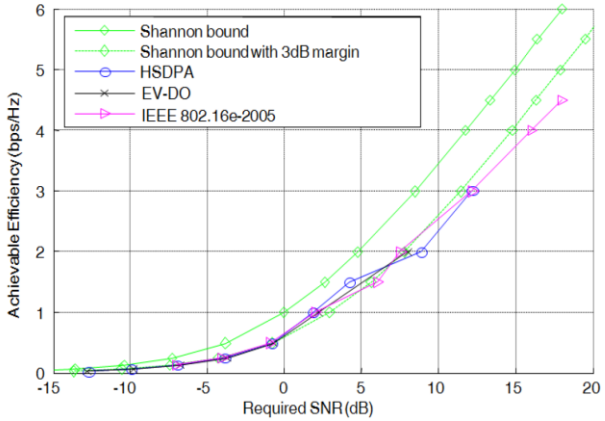


4G와 5G를 고속도로에 비유

5G 무선채널 용량 증대



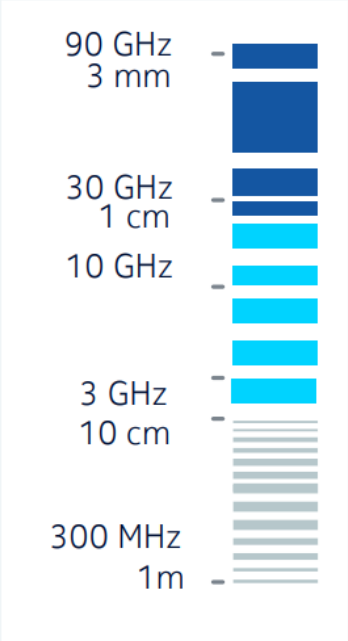
- 통신채널의 용량은 샤논(Shannon) 법칙에 따라 정해짐
  - 채널 용량은 주로 주파수 폭과 안테나 수에 비례
- 5G는 광대역 주파수 폭과 다수의 송수신 안테나를 사용하여 용량 증대
- 참고: 주파수 폭과 안테나 수 증가 이외에 다른 방법이 없음
  - 이미 가용할 수 있는 모든 기술이 적용되어 채널용량 한계치에 도달



주요기술

5G에 적용된 주요기술 예(1)

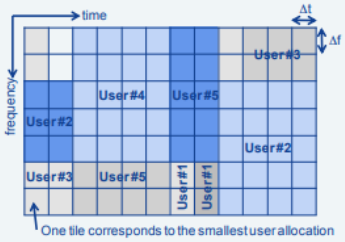
#1 New spectrum



#2 Beamforming

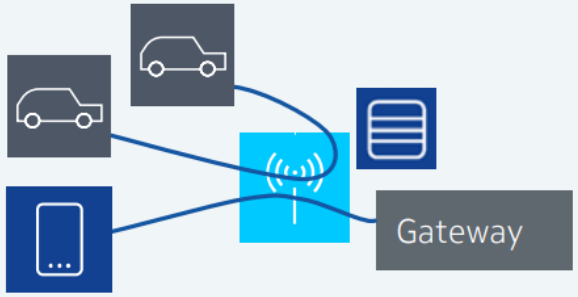
#4 Dual connectivity

#3 Slicing and flexibility



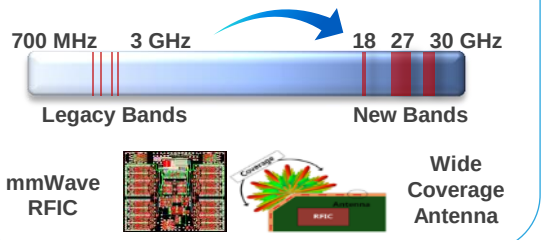
- Lean carrier
- Flexible size, control, TDD, bandwidth etc

#5 Edge computing

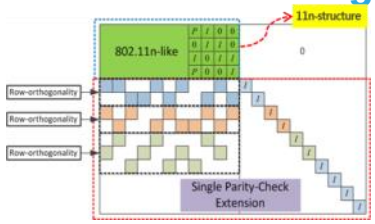


5G에 적용된 주요기술 예(2)

mmWave System/RFIC/Ant.

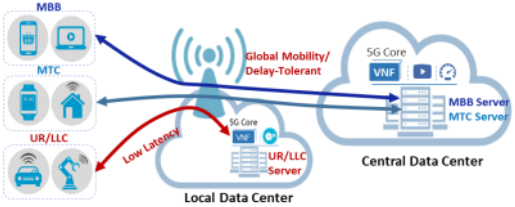


New Channel Coding

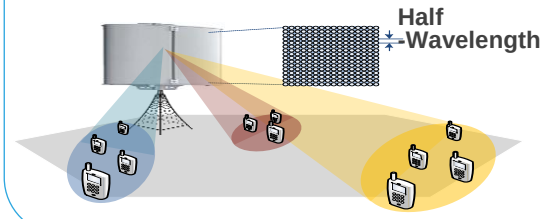


LDPC (Low-Density Parity-Check)

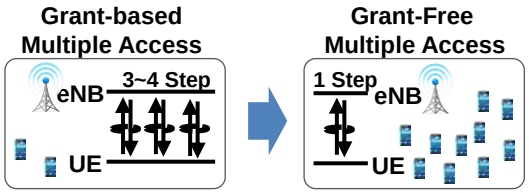
Network Slicing



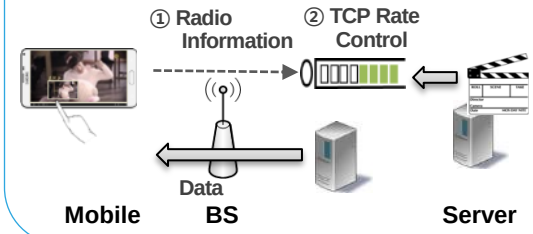
< 6 GHz Massive MIMO



Massive Connectivity (IoT)

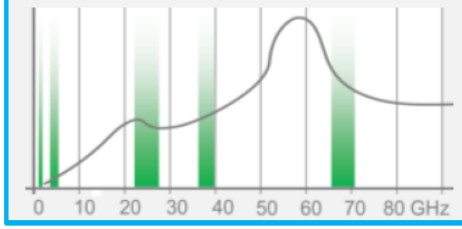


Low Latency NW



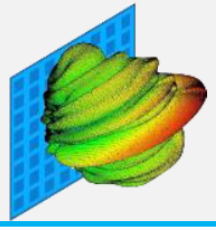
5G에 적용된 주요기술 예(3)

New Spectrum



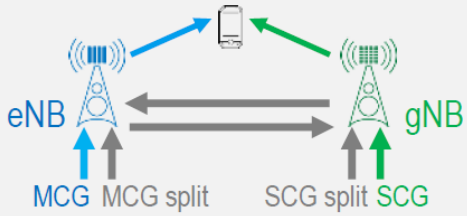
- < 1GHz
- ~ 3.5 GHz
- ~ 26/28/39 GHz

Massive MIMO & Beamforming



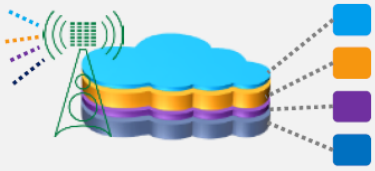
- Hybrid beamforming
- > 6GHz also UE is expected to apply beam steering

Multi-Connectivity



Initially based on Dual Connectivity with E-UTRA as master

Network flexibility - virtualization



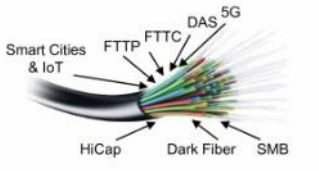
- Flexible physical layer numerology
- Network Slicing
- NFV/SDN

5G에 적용된 주요기술 예(4)

Critical Technologies for 5G

5G

- FIBER
- SPECTRUM
- SOFTWARE DEFINED NETWORKS
- MULTI-ACCESS EDGE COMPUTE (MEC)

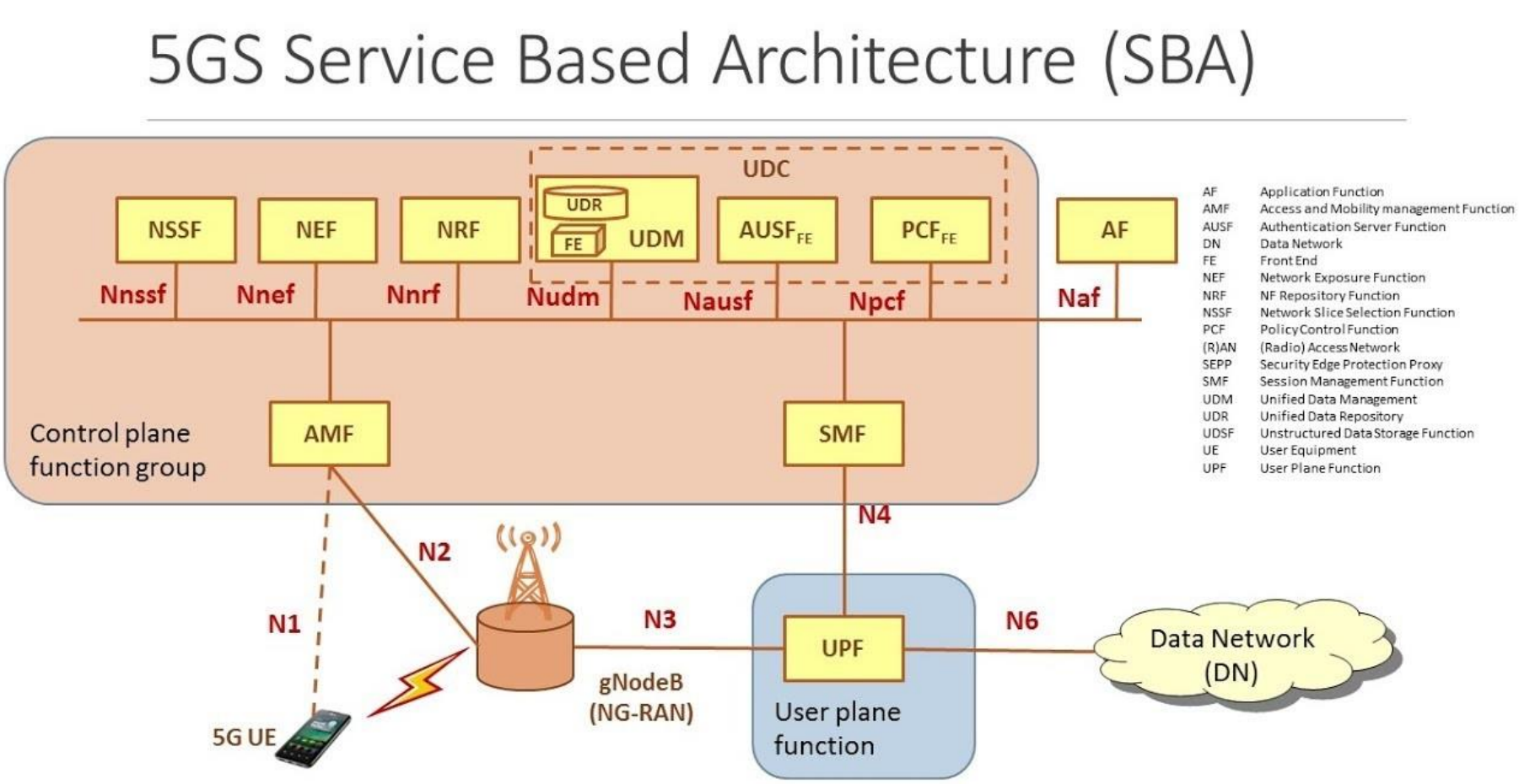


verizon

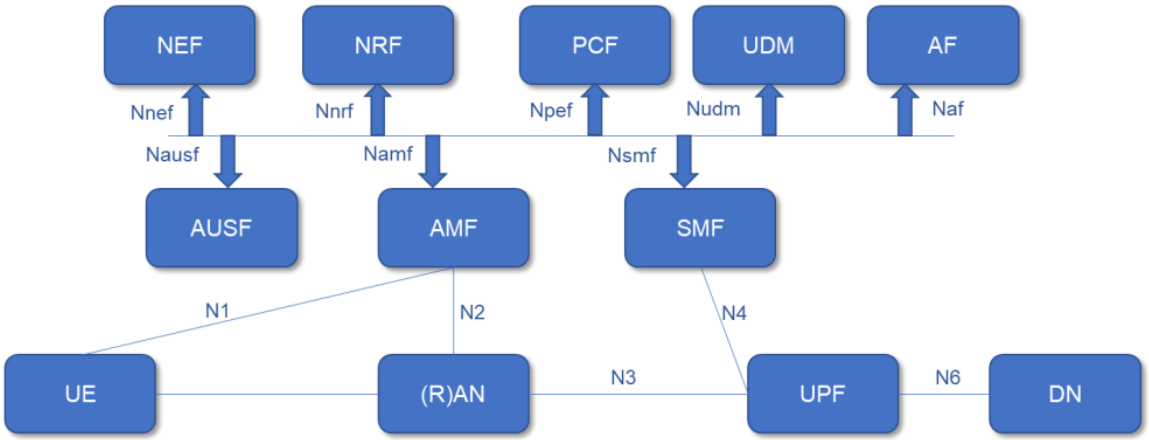
5G의 가장 큰 특징(4G 대비)

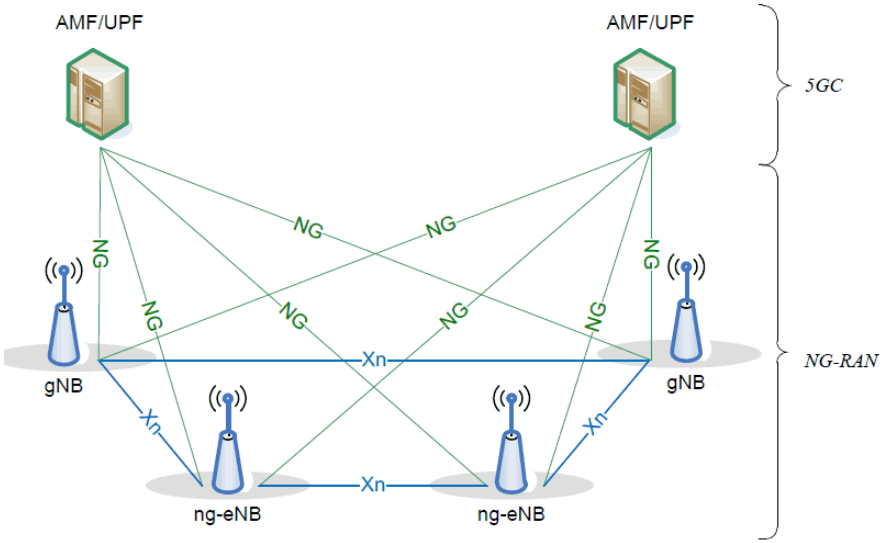
5G의 가장 큰 기술적인 차이점(4G 대비)은 새로운 주파수 대역(New Radio)에 광대역 주파수를 사용하는 것임

5G Network Architecture(1)



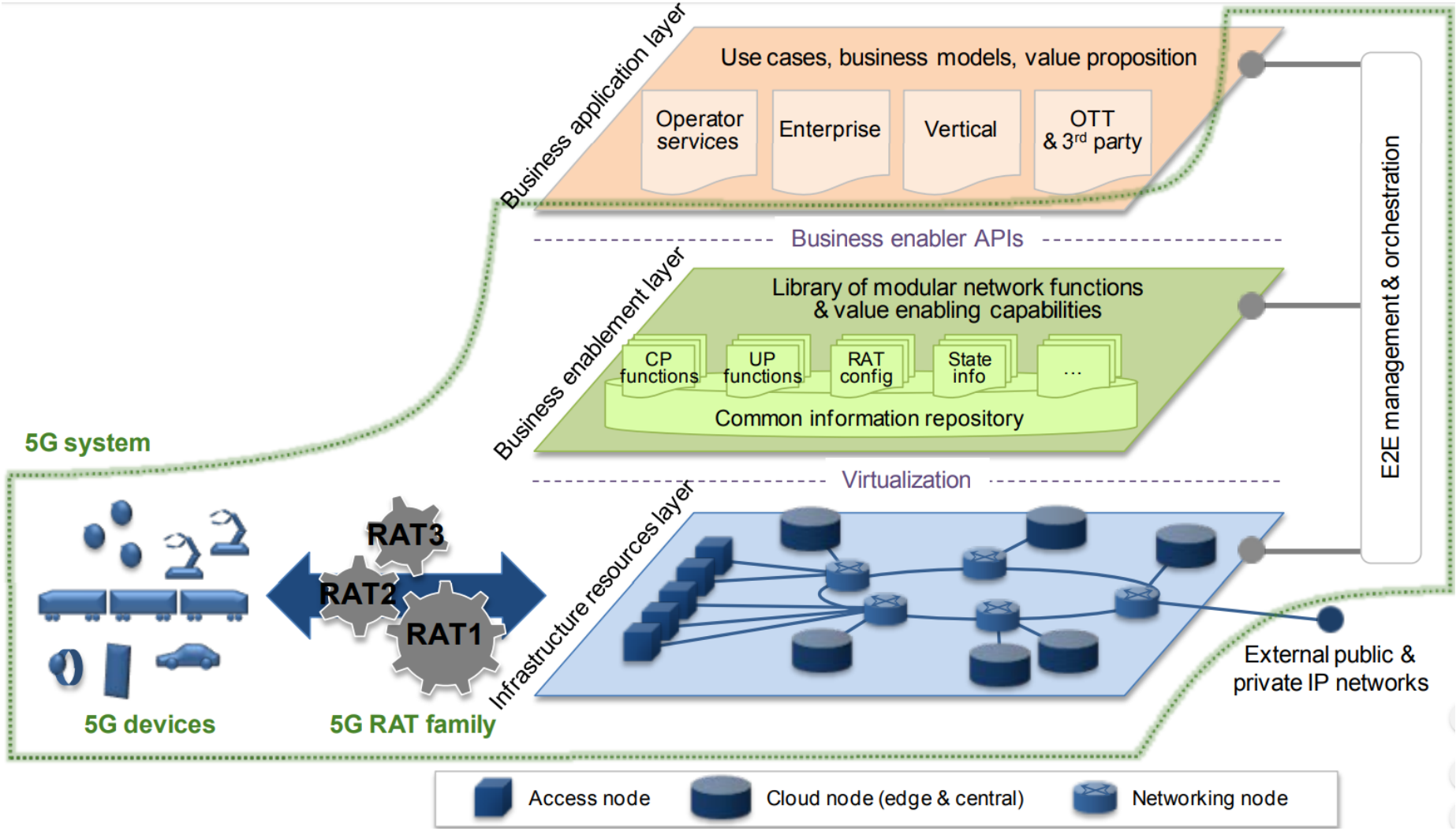
5G Network Architecture(2)



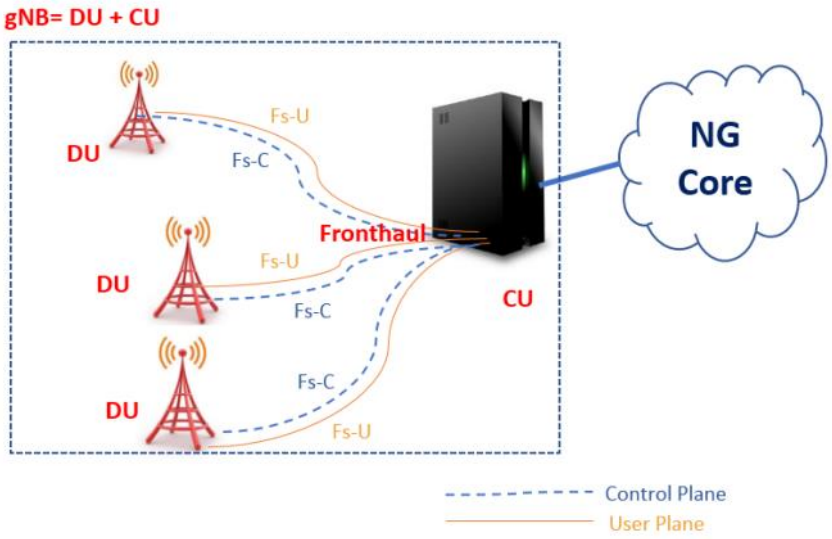


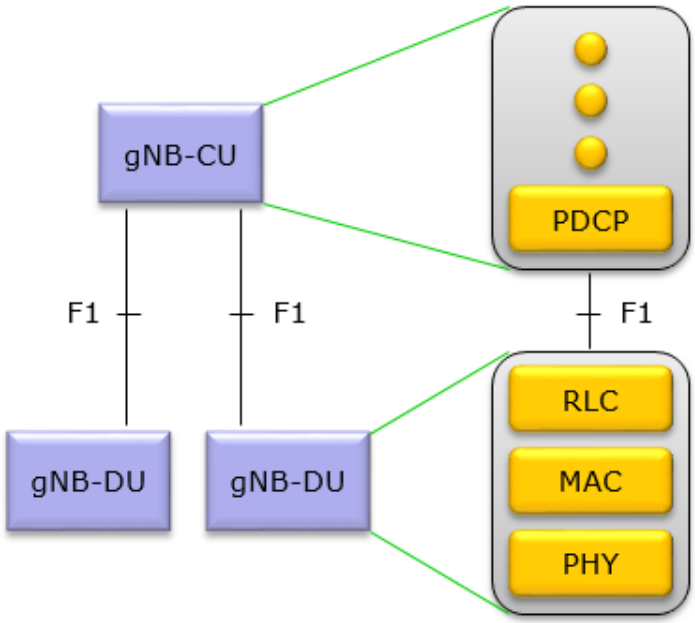
- 5G 통신망은 다양한 서비스 제공을 위한 방향으로 정의되었음
  - 이러한 구조를 SBA라고 함 (Service Based Architecture)
  - SDN, NFV, Network Slicing, MEC
- 코어망 요소: AMF, SMF 등
- 기지국: gNB
  - next generation Node B

5G 기반 SBA - NGMN



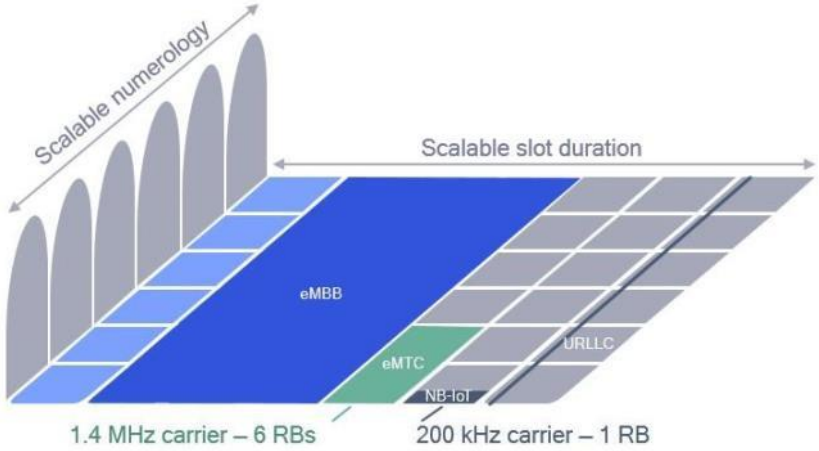
5G gNB 구조

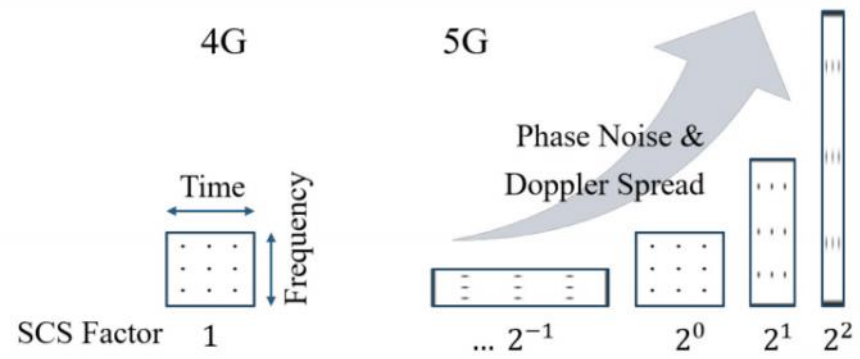

gNB= DU + CU
DU
DU
DU
Fs-U
Fs-C
Fs-U
Fs-C
Fs-C
Fs-U
Fronthaul
CU
NG
Core
Control Plane
User Plane


gNB-CU
F1
F1
F1
gNB-DU
gNB-DU
PDCP
RLC
MAC
PHY

5G OFDMA

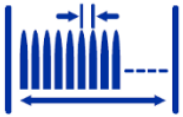
OFDMA: Orthogonal Frequency Division Multiple Access





Sub-Carrier Scalable OFDMA

Outdoor and macro coverage
FDD / TDD <3 GHz

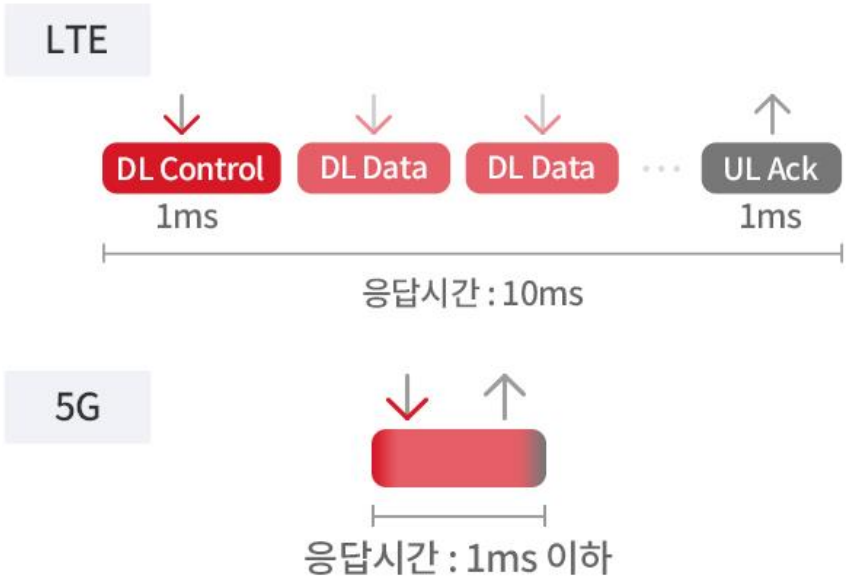


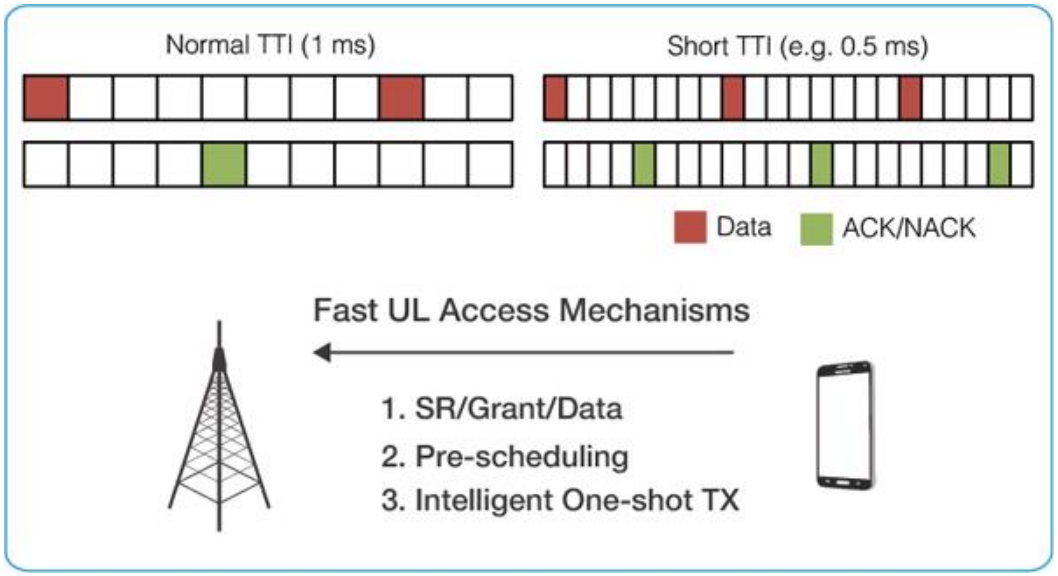
Outdoor and small cell
TDD > 3 GHz

Indoor wideband
TDD e.g. 5 GHz (Unlicensed)

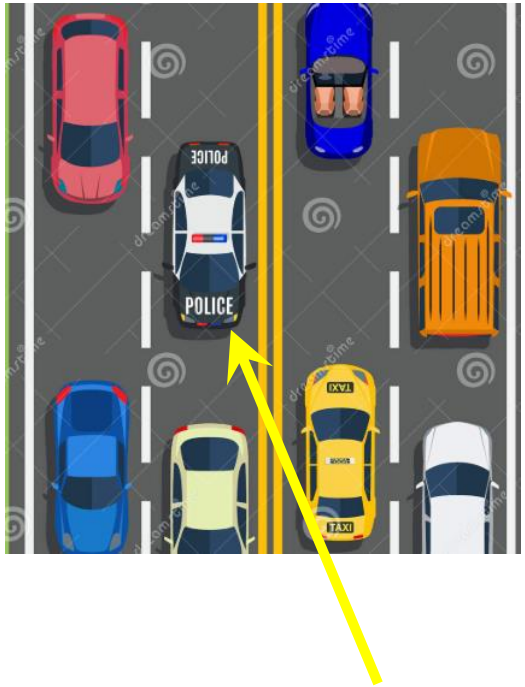
mmWave
TDD e.g. 28 GHz

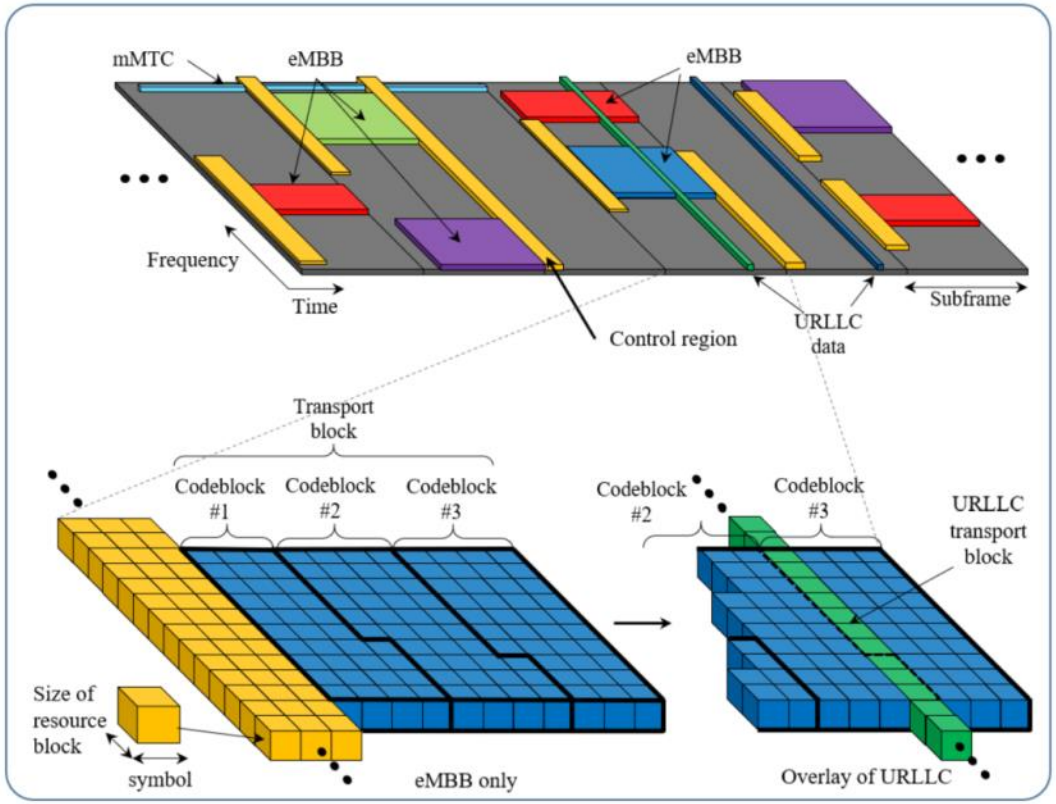
Low Latency 구현 예





OFDMA에서 URLLC Overlay





4x4 MIMO, 256 QAM

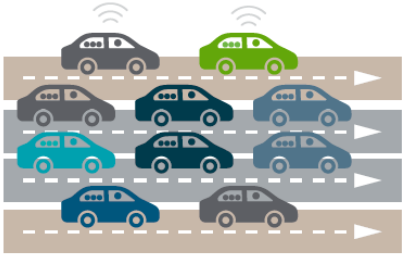
The technology enabling the data super highway
(where passenger = data)

For this example, think of baseline LTE technology as
a single highway with standard size cars traveling on it.

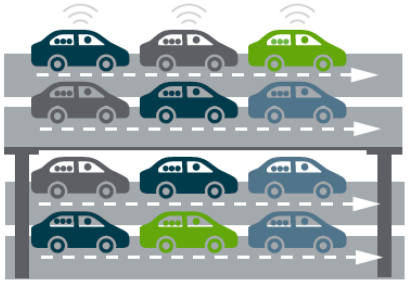
Highway expansion

Carrier Aggregation
is like adding a highway

Unlicensed Band
is like moving some traffic
to parallel service roads



4x4 MIMO
is like adding a highway
on top of a highway

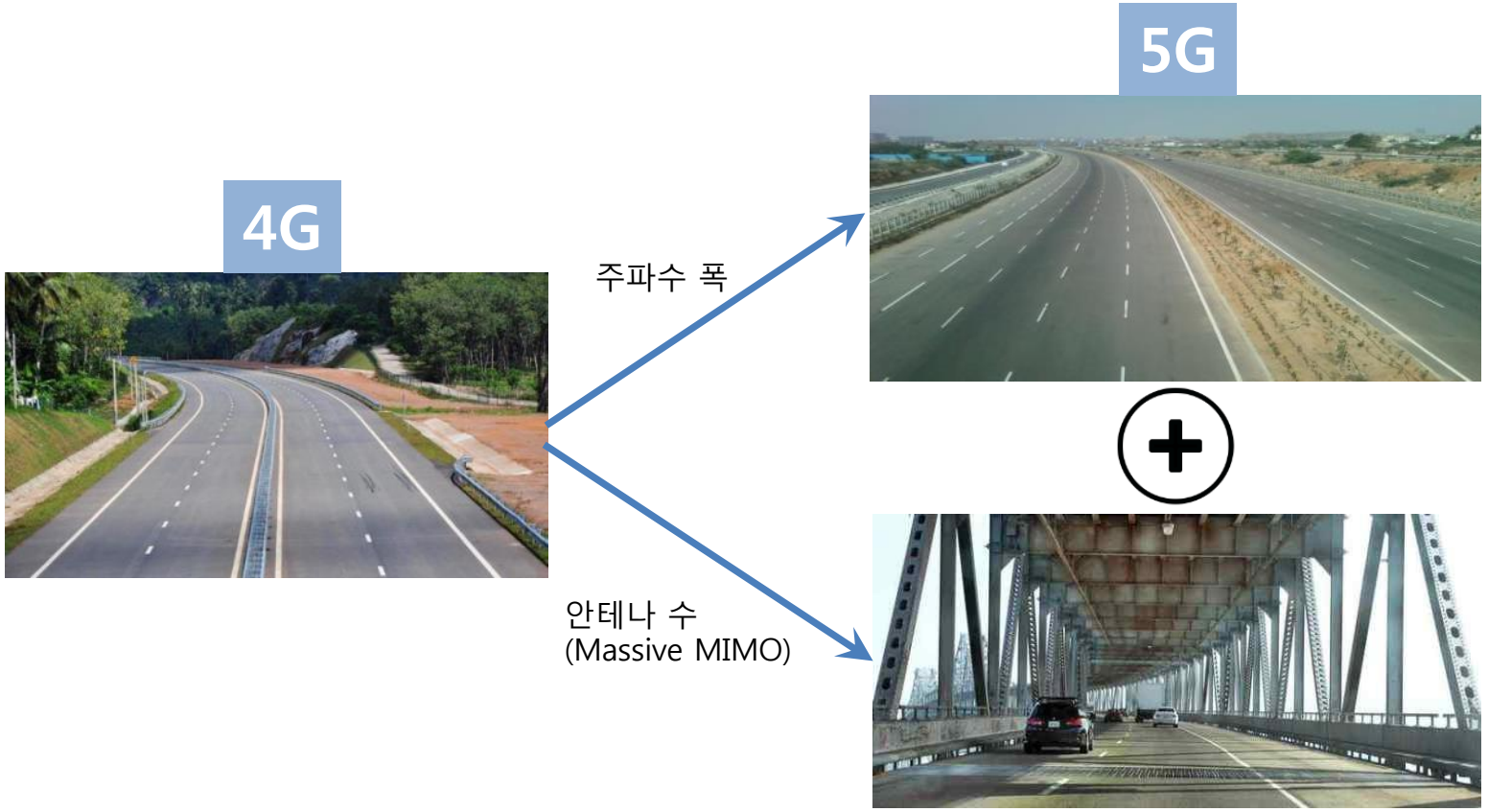


Additional passengers per vehicle

256 QAM
is like adding more people per vehicle

* MIMO: Multiple Input Multiple Output

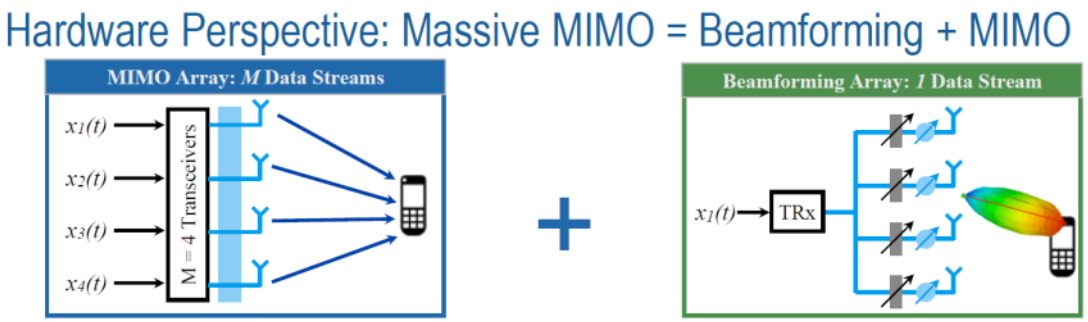
5G에서 초고속 통신

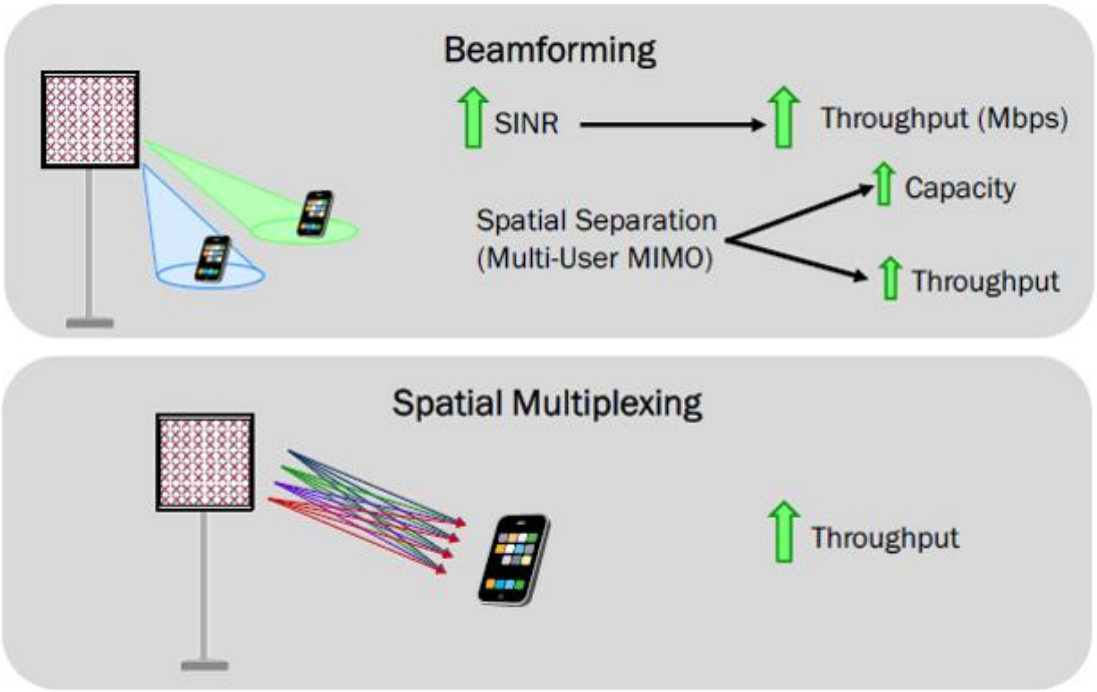


- 5G는 4G 대비 넓은 주파수 폭과 Massive MIMO로 전송속도를 증가시킴
  - 광대역 주파수 폭: 고속도로 차선수 추가
  - Massive MIMO: 고속도로 위에 제 2 고가도로 건설

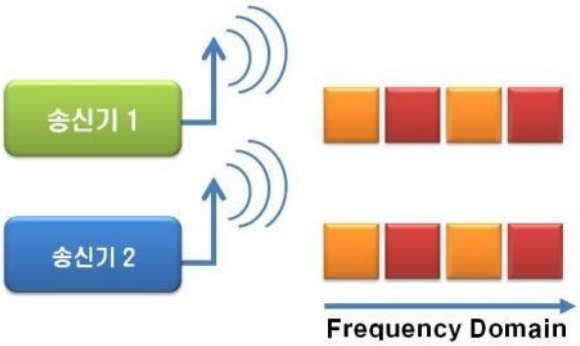
* 이 외에 High Order 변조 방식(ex, 256 QAM)도 사용

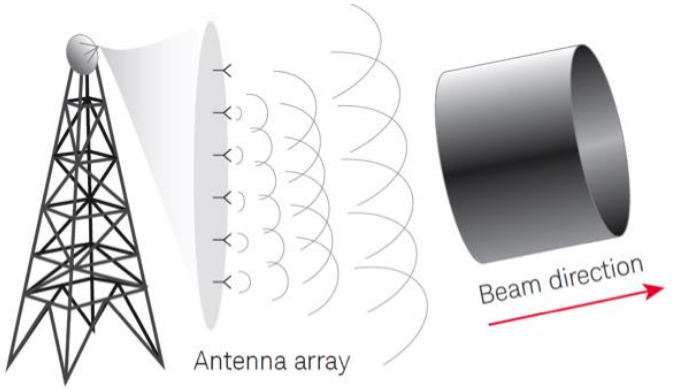
Massive MIMO = Beamforming + MIMO

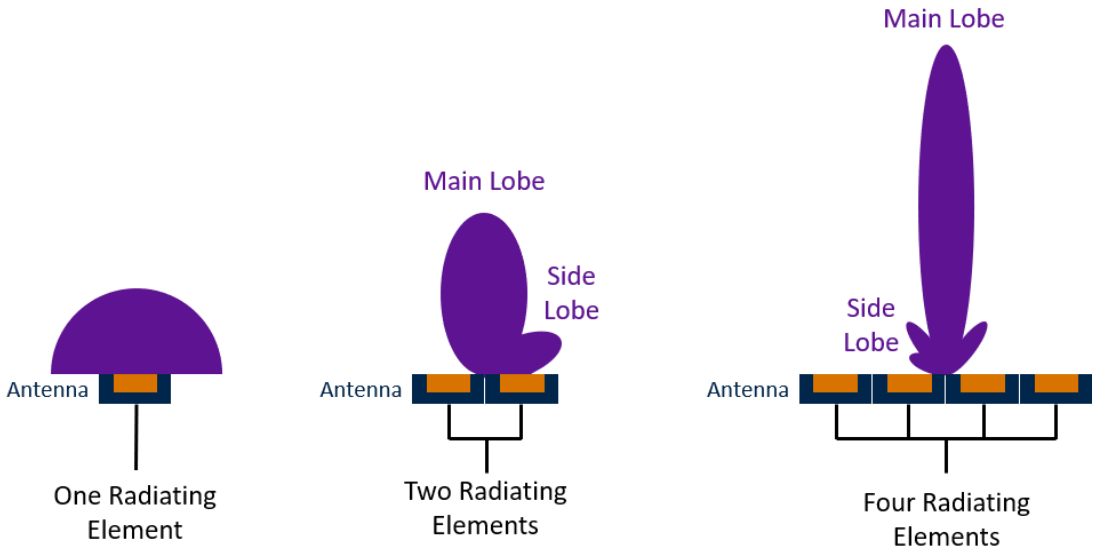




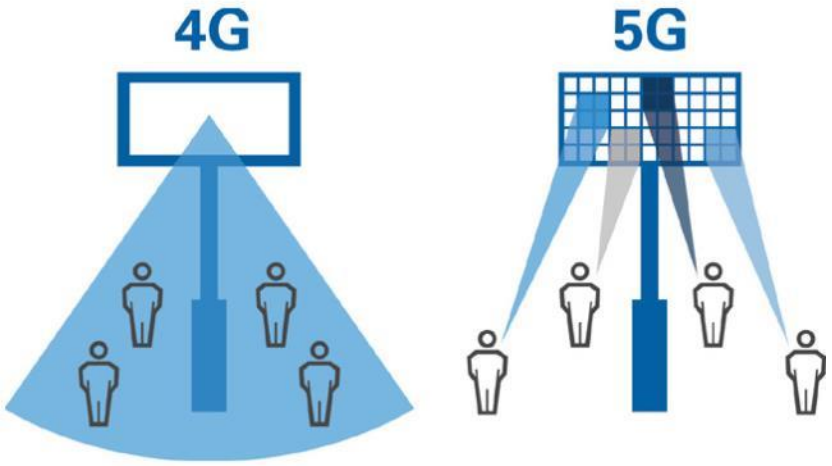
Massive MIMO의 Beam Forming





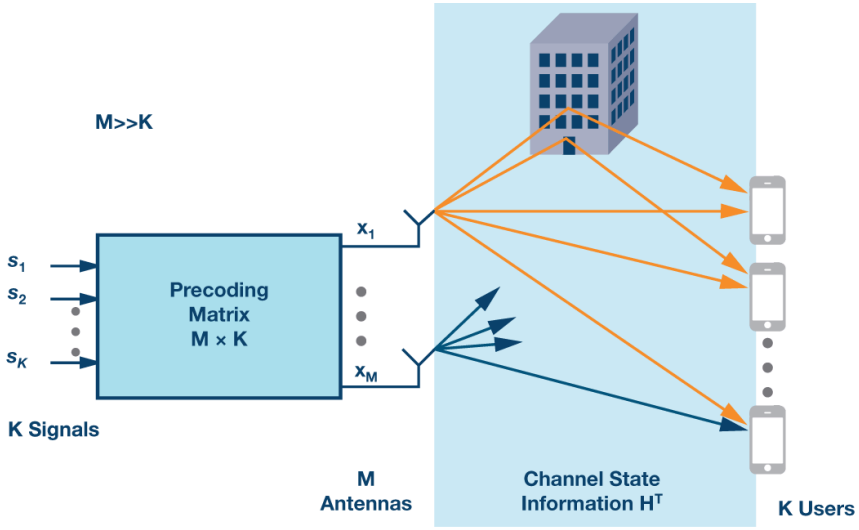


Massive MIMO의 Beam Forming/Tracking

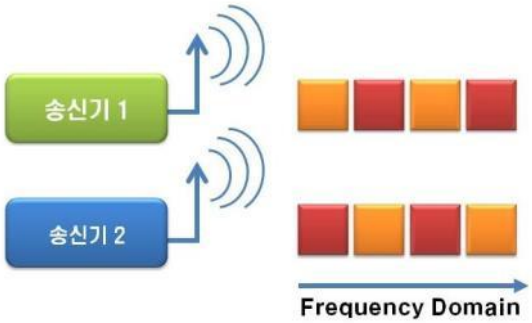


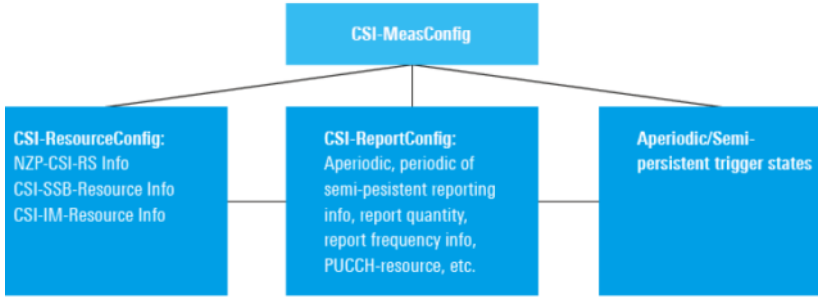
- 5G는 해당 사용자 별로 Beam Forming(전파 에너지 집중)
  - Beam Forming은 Massive MIMO가 되어야 가능함
- 5G의 초고주파 대역(예, 28GHz)에서 전파감쇄를 보완하기 위한 방법
- Beam Forming이 활성화될 경우, 기존 셀 형상에 변화가 있음

Massive MIMO의 Spatial Multiplexing



Precoding Type	
Maximum Ratio (MR)	$\mathbf{x} = H^*\mathbf{s}$
Zero Forcing (ZF)	$\mathbf{x} = H^*(H^TH^*)^{-1}\mathbf{s}$
NMSE or RZF	$\mathbf{x} = H^*(H^TH^* + \beta I)^{-1}\mathbf{s}$





* CSI-RS: Channel Status Information – Reference Signals

NSA, SA Operation

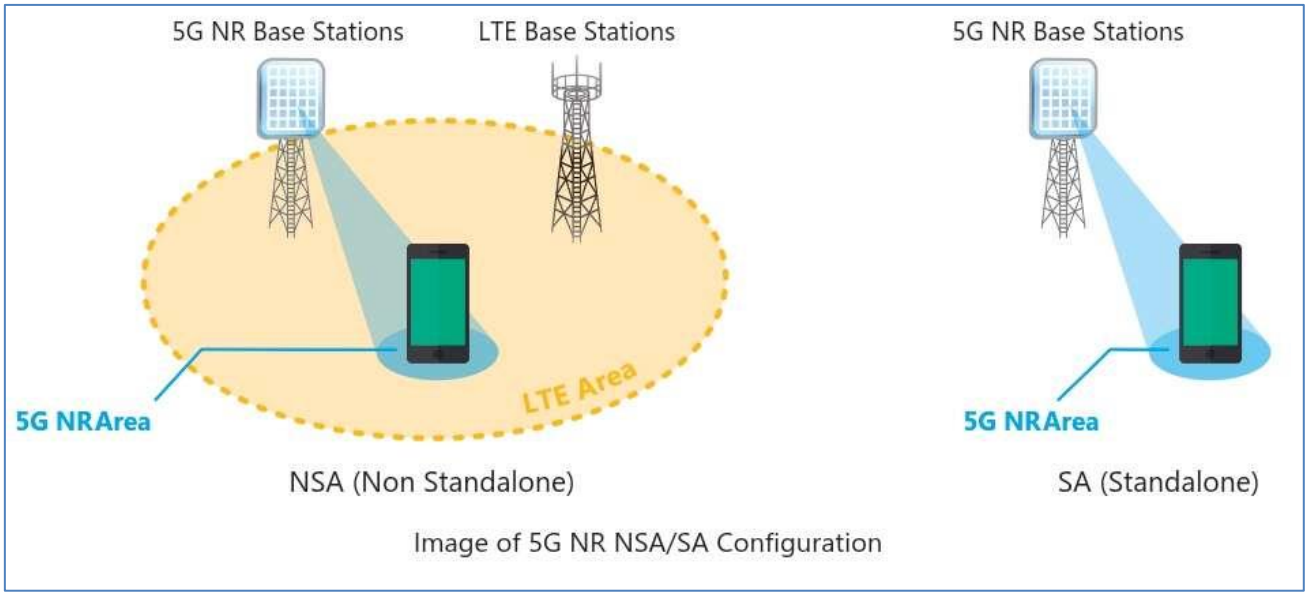
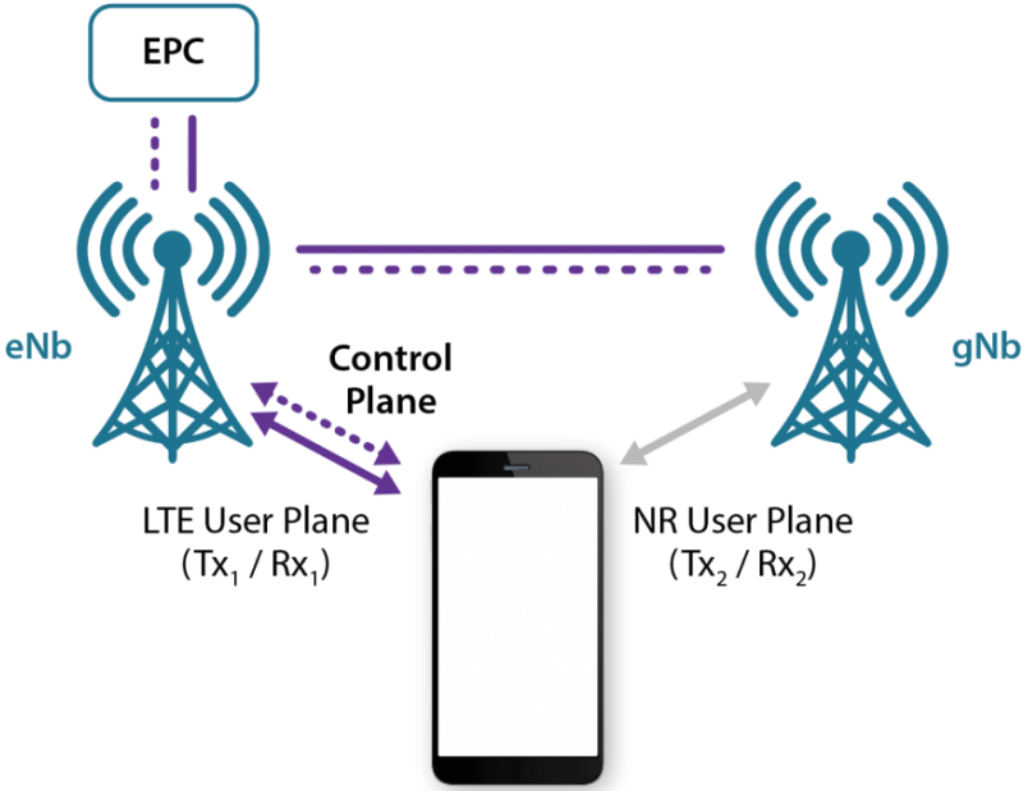


Image of 5G NR NSA/SA Configuration

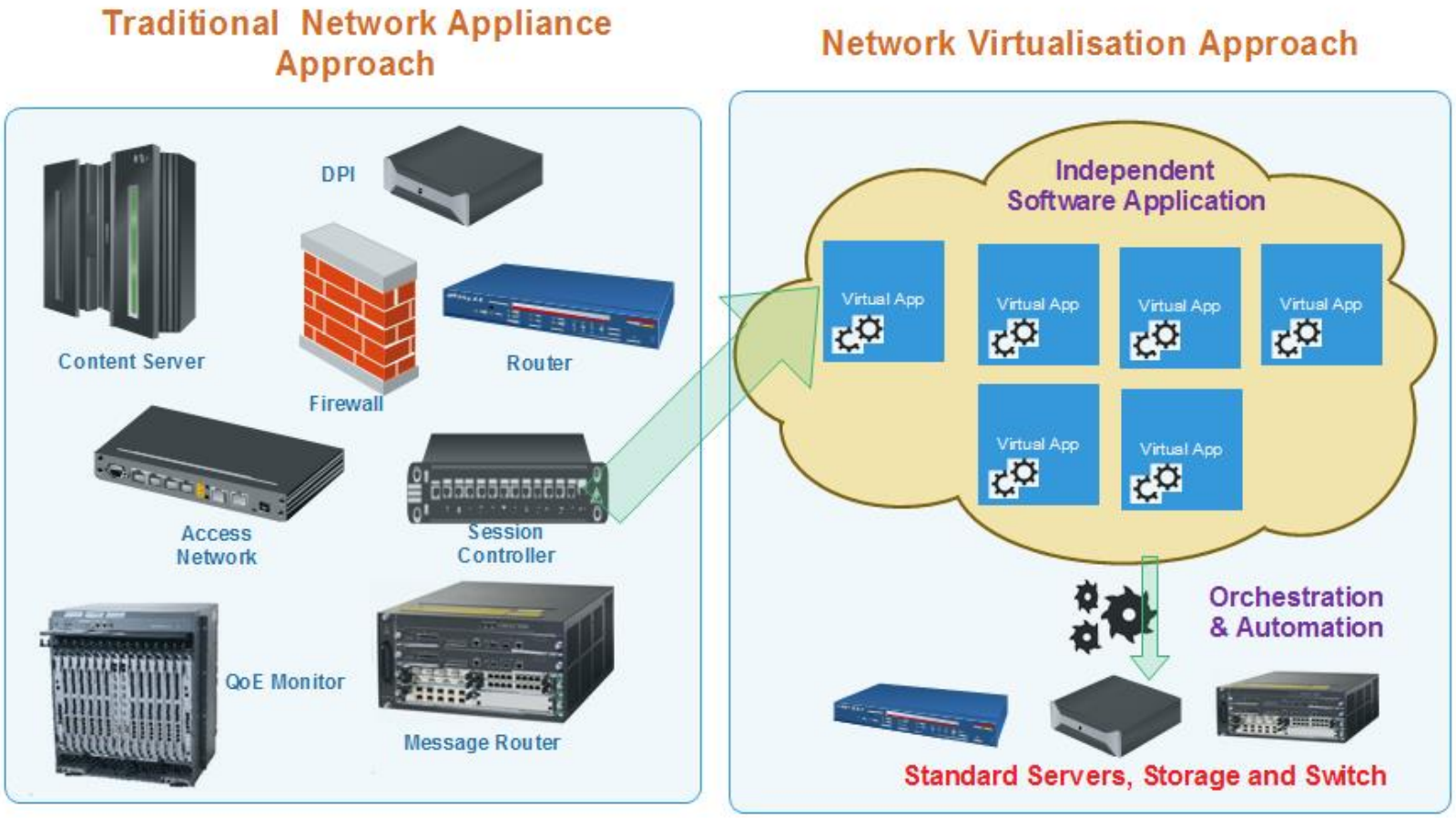
- 3GPP는 5G망을 점진적으로 구축하기 위하여 NSA, SA 동작 모드 정의
  - NSA(Non Standalone): 4G+5G로 운용
  - SA(Standalone): 5G 단독망으로 운용
  - NSA를 정의한 이유는 5G 통신장비 초기 투자비를 절감하기 위함 (mmWave의 경우, 5G 기지국 수는 4G 대비 4배 이상)

- NSA는 4G망과 연동을 위하여 단말기의 제어신호는 4G망을 활용하고, 데이터 송수신은 5G망을 활용

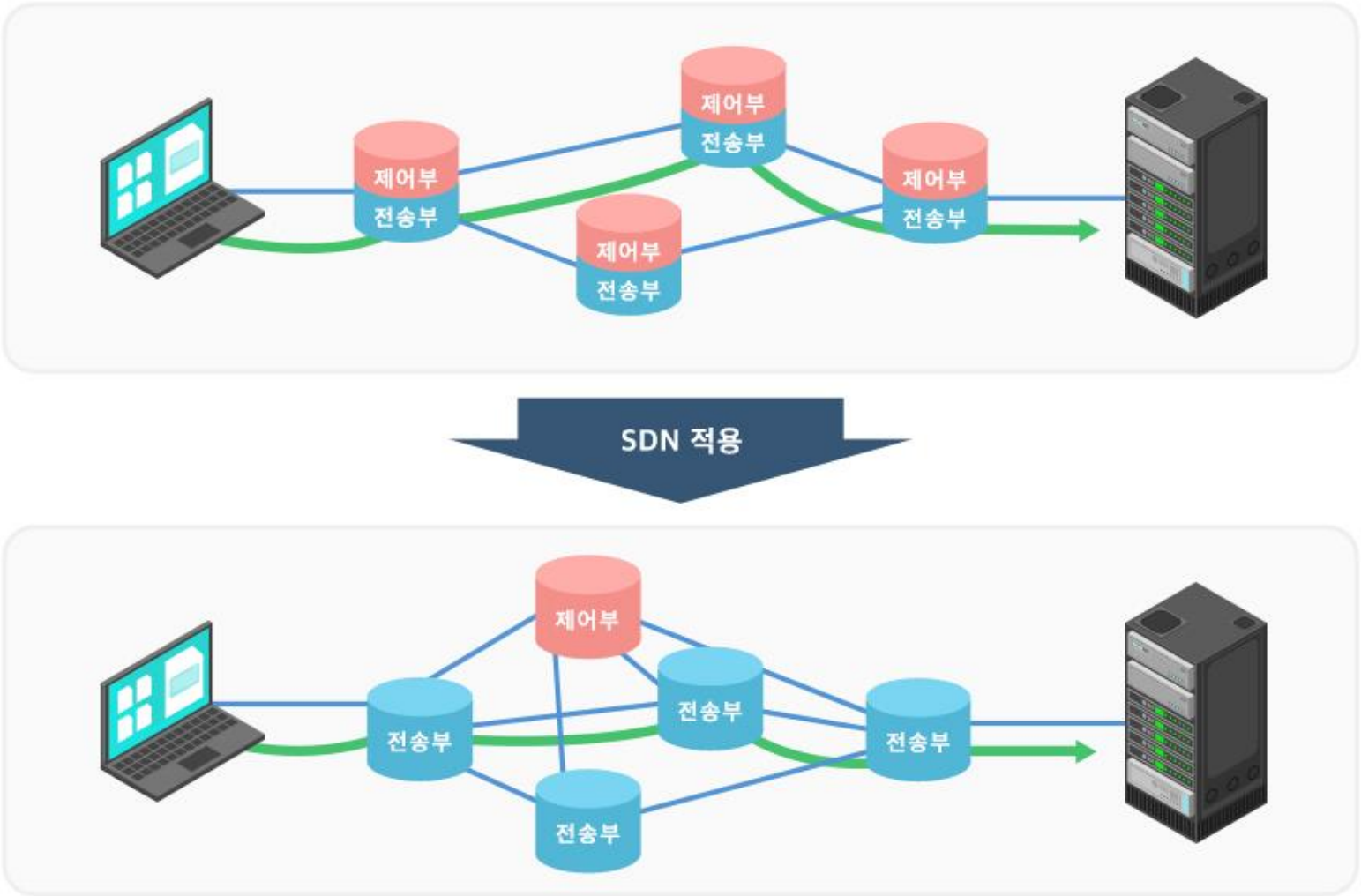
NSA Dual Connectivity



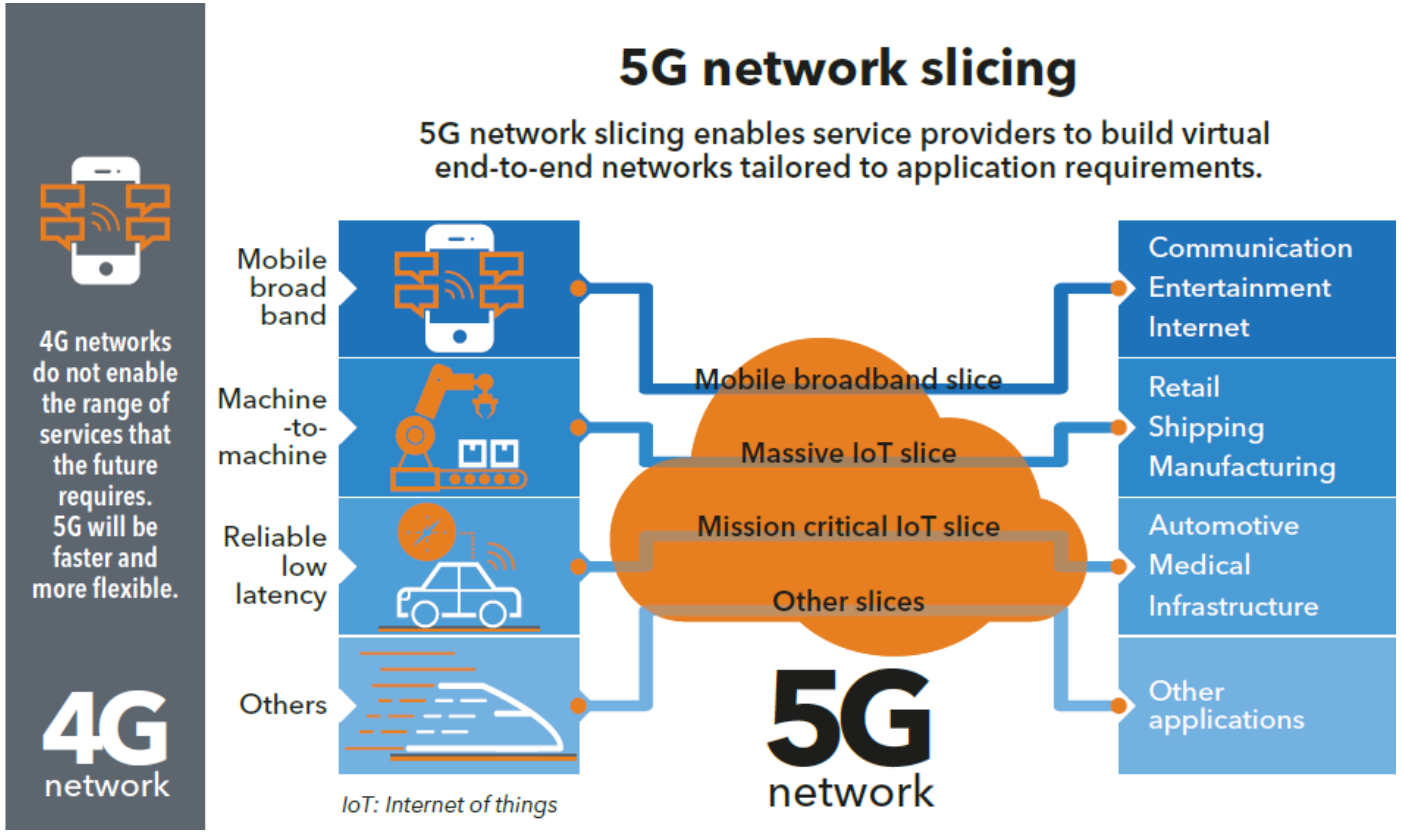
NFV: Network Function Virtualization



SDN: Software Defined Network

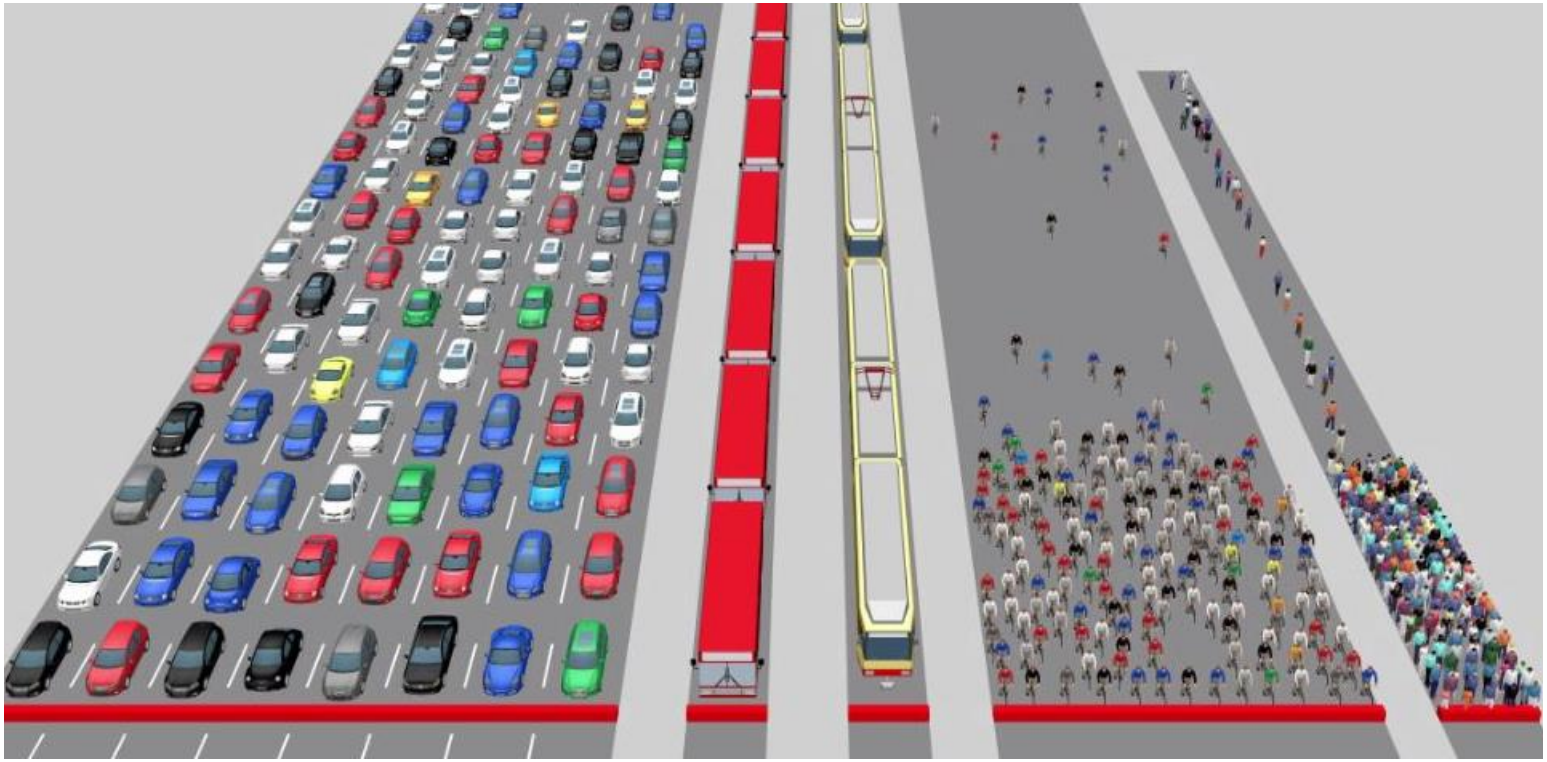


Network Slicing(1)

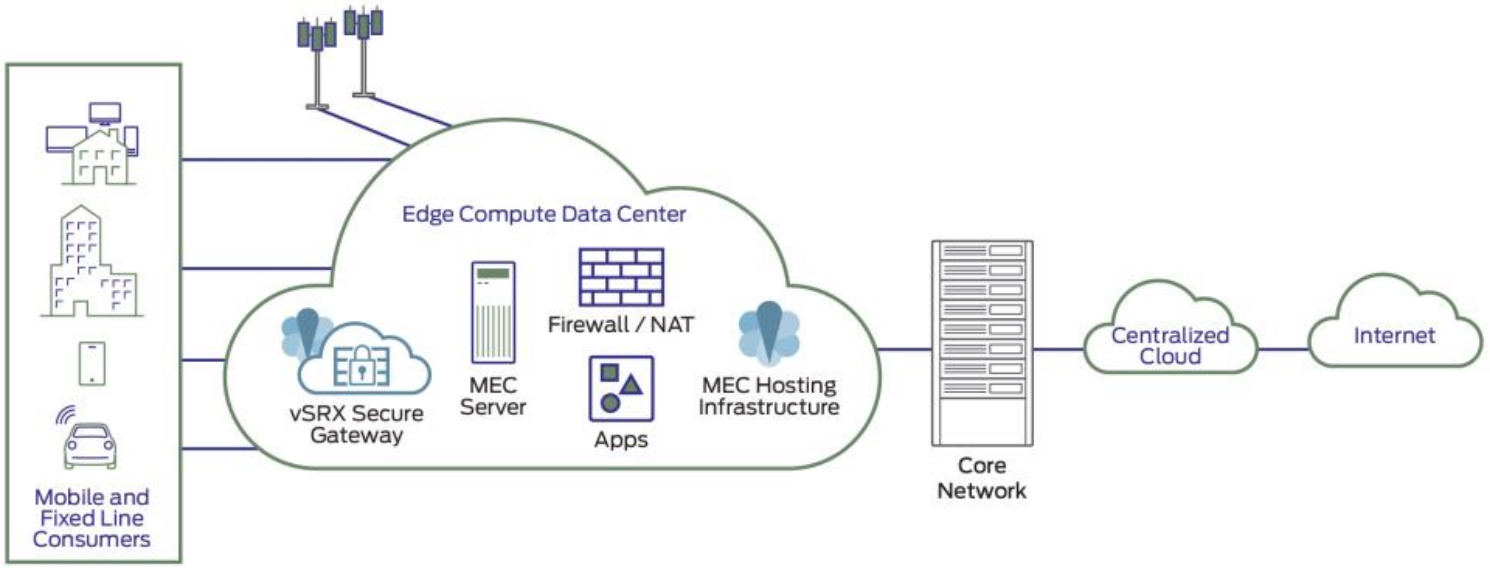


- Network Slicing은 코어망의 기능을 QoS에 따라서 별도로 처리하는 기능
- 서비스 특성별로 다르게 처리하여 다양한 서비스 처리
- 4G의 경우, 음성(VoLTE)와 일반 데이터만 구분됨

Network Slicing(2)



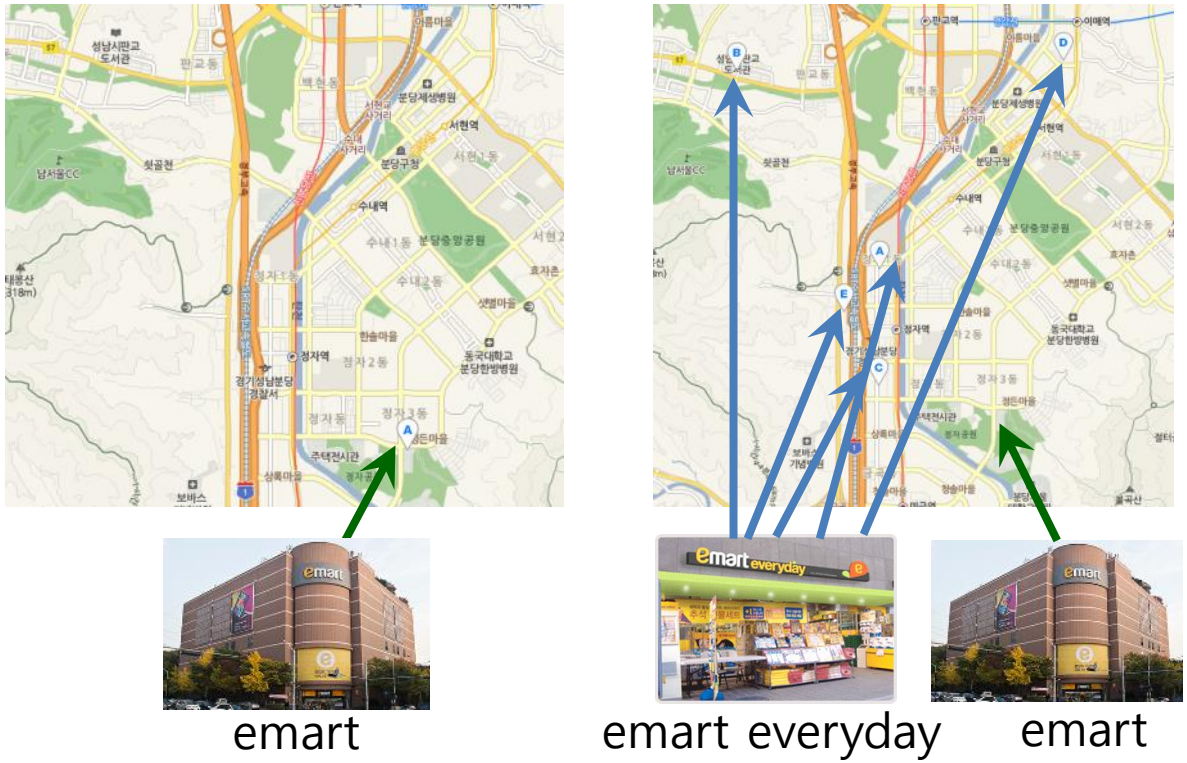
Mobile Edge Computing(1)



- 5G망에 적용되는 MEC(Mobile Edge Computing)는 사용자가 자주 사용하는 앱, 컨텐츠, 서비스 등을 기지국 가까이 위치시켜 통신망 트래픽을 줄이고, 사용자에게 빠른 서비스를 제공하기 위한 목적

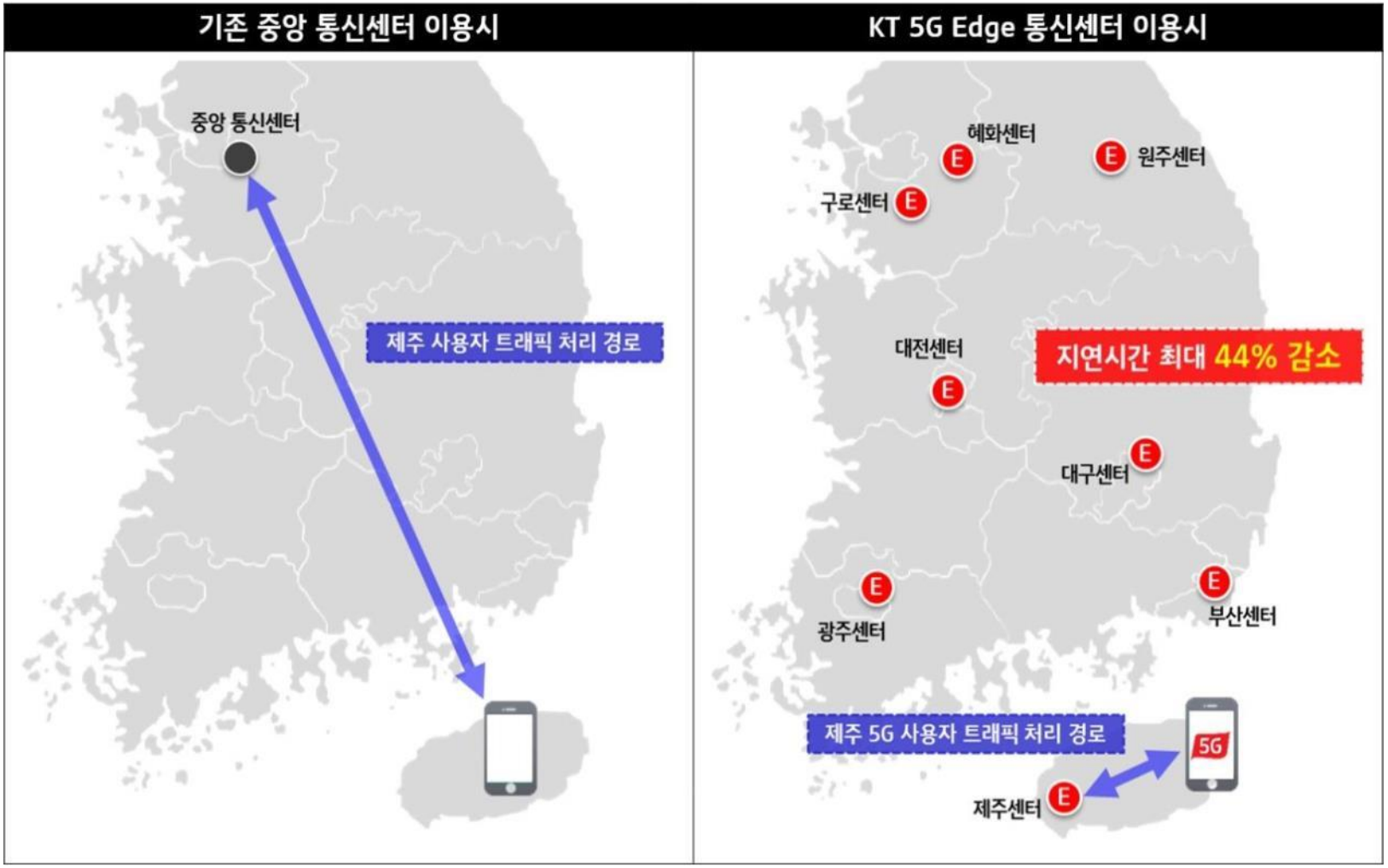
- 5G의 MEC는 4G에 없었던 기능으로 자율주행차, 공장자동화, Tactile Internet 등을 위하여 필수적인 망 구성 요소임

Mobile Edge Computing(2)

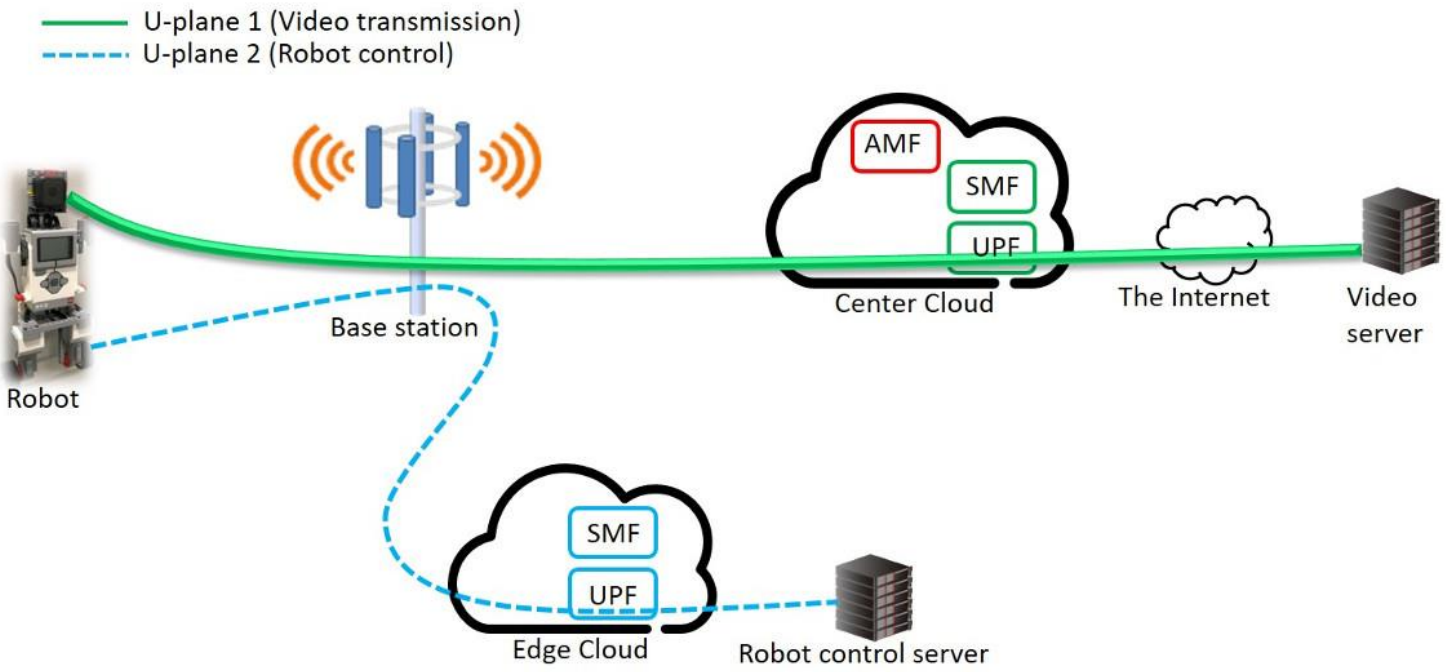


- 5G망 MEC(Mobile Edge Computing)는 emart와 emart everyday에 비유
  - emart(대형매장): 대용량 Cloud
  - emart everyday(소형매장): MEC(자주 사용하는 물건만 판매)

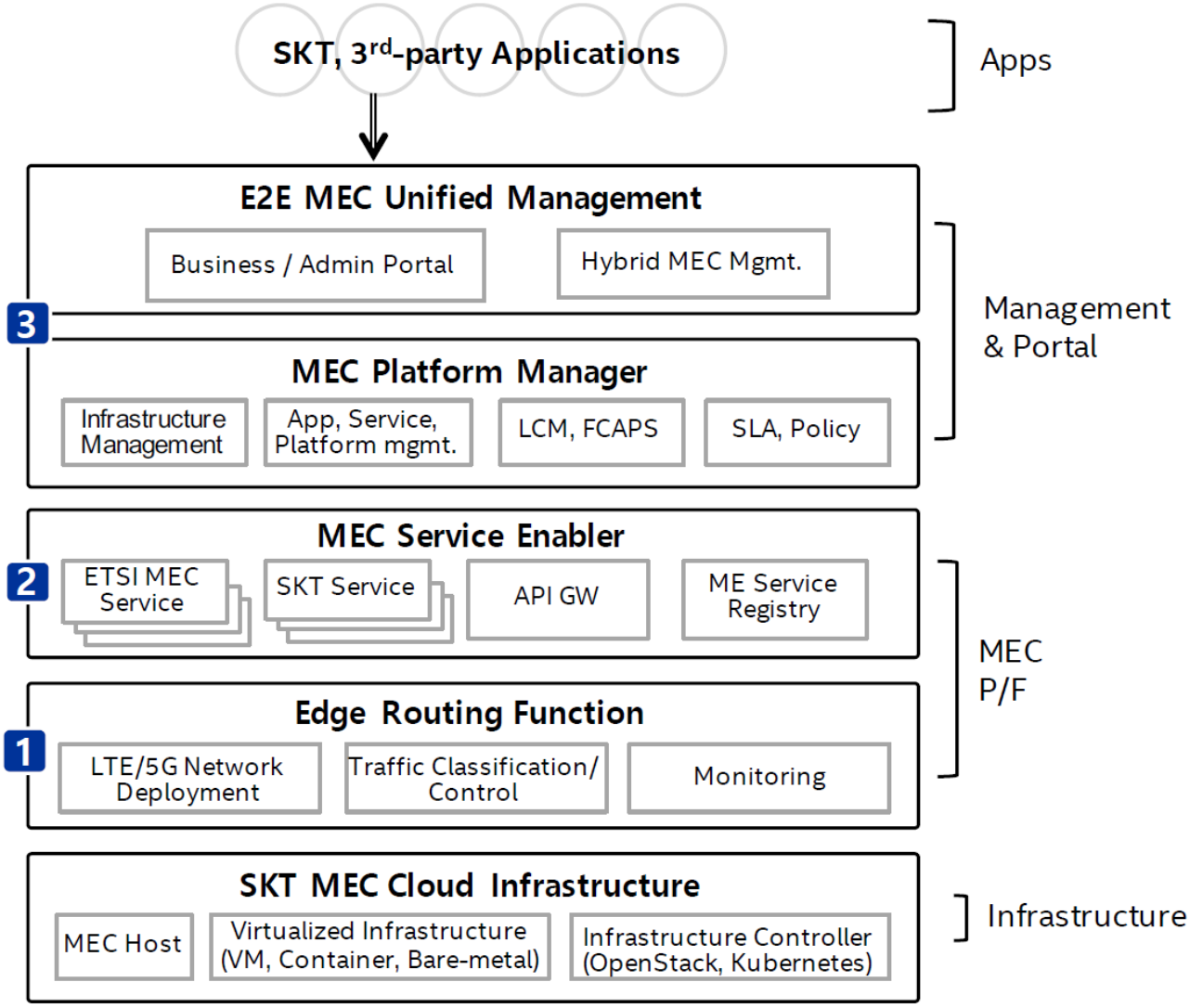
Mobile Edge Computing(3)



MEC, User Plane Path

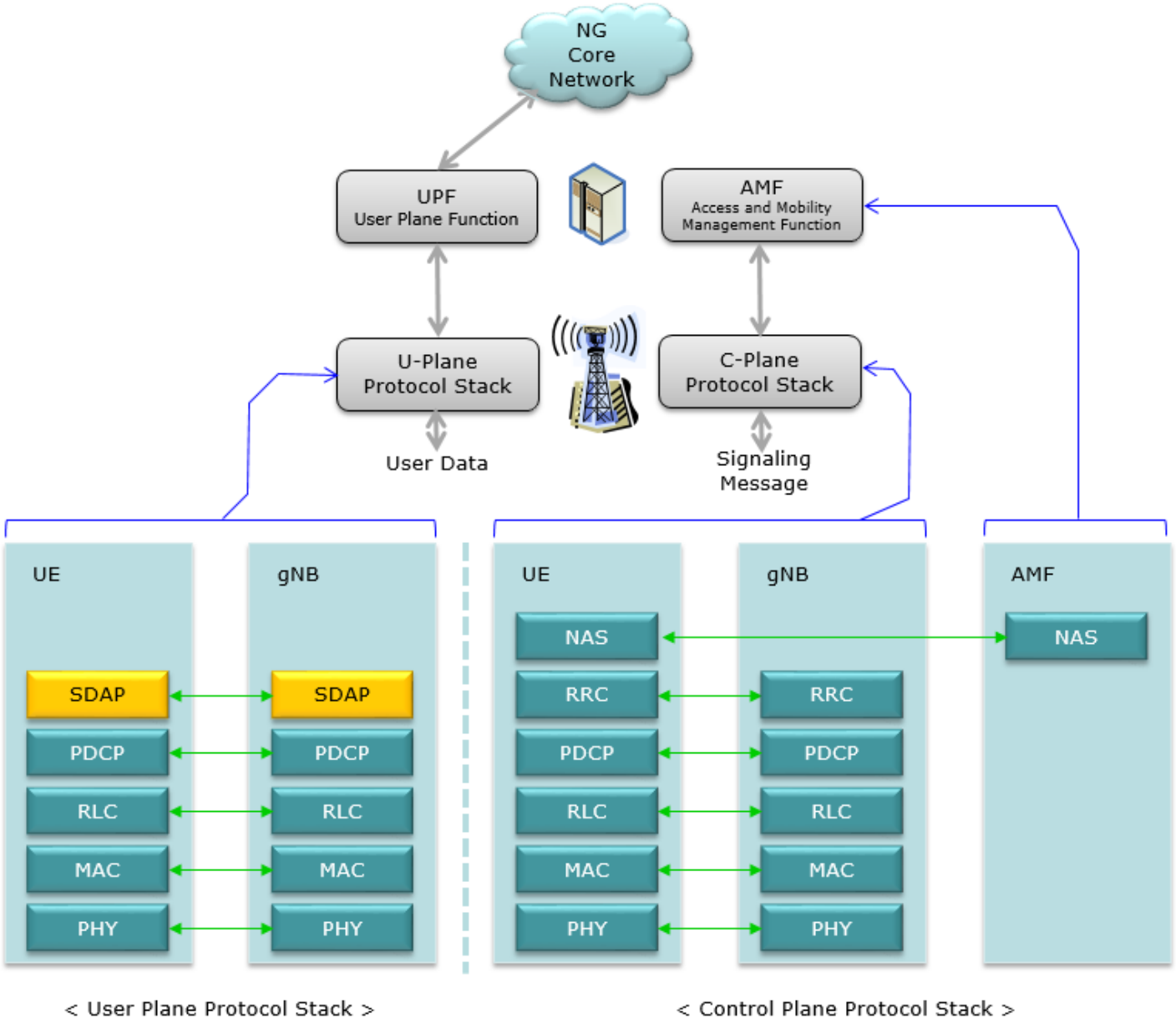


MEC 구현 예


SKT, 3rd-party Applications
Apps
E2E MEC Unified Management
Business / Admin Portal
Hybrid MEC Mgmt.
3
MEC Platform Manager
Infrastructure Management
App, Service, Platform mgmt.
LCM, FCAPS
SLA, Policy
Management & Portal
MEC Service Enabler
2
ETSI MEC Service
SKT Service
API GW
ME Service Registry
MEC P/F
Edge Routing Function
1
LTE/5G Network Deployment
Traffic Classification/ Control
Monitoring
SKT MEC Cloud Infrastructure
MEC Host
Virtualized Infrastructure (VM, Container, Bare-metal)
Infrastructure Controller (OpenStack, Kubernetes)
Infrastructure

호처리

5G User Plane, Control Plane



< User Plane Protocol Stack >

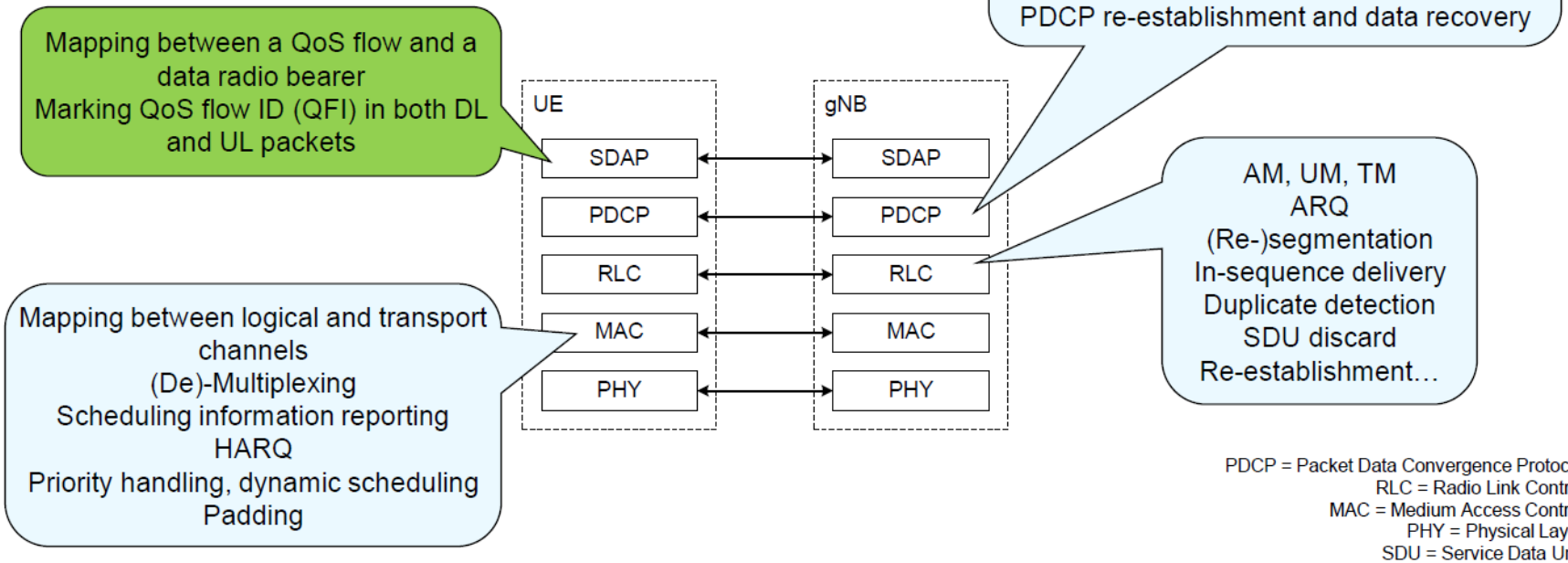
< Control Plane Protocol Stack >

* SDAP: Service Data Adaptation Protocol

5G User Plane

Protocol stack

User plane

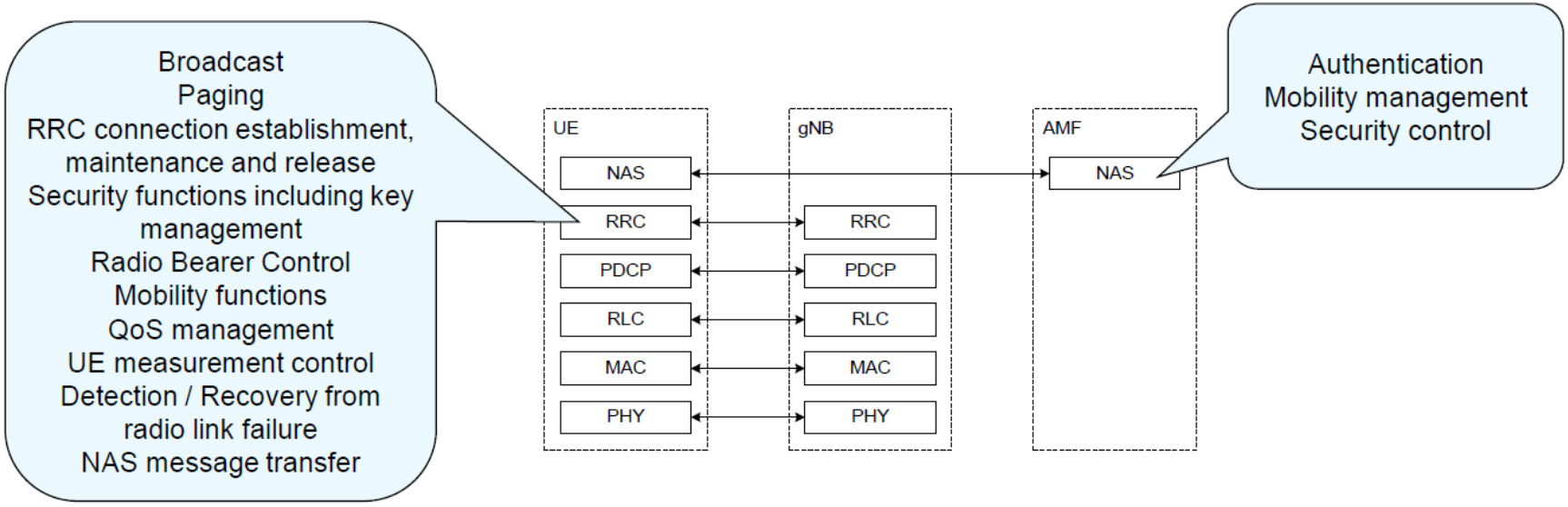


PDCP = Packet Data Convergence Protocol
RLC = Radio Link Control
MAC = Medium Access Control
PHY = Physical Layer
SDU = Service Data Unit
(H)ARQ = (Hybrid) Automatic Repeat Request

5G Control Plane

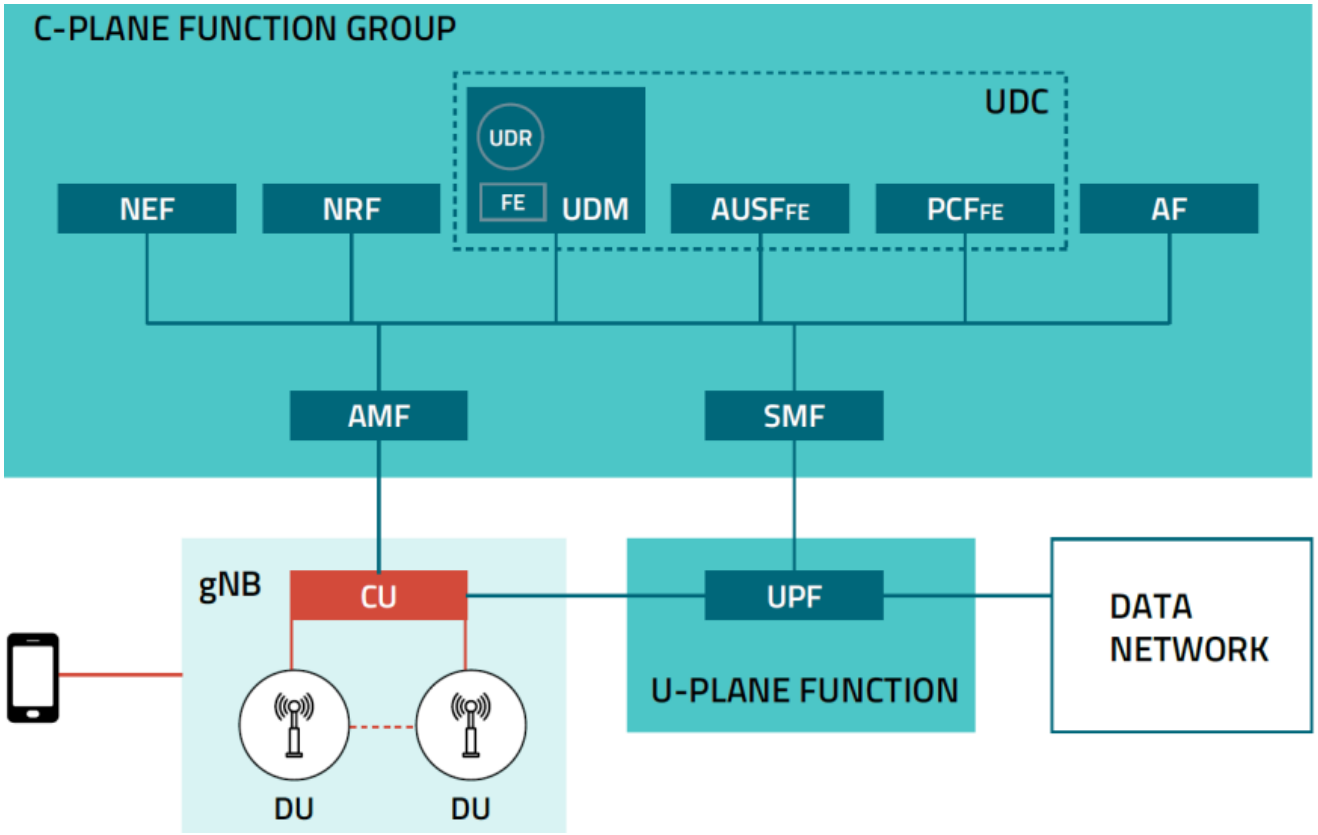
Protocol stack

Control plane



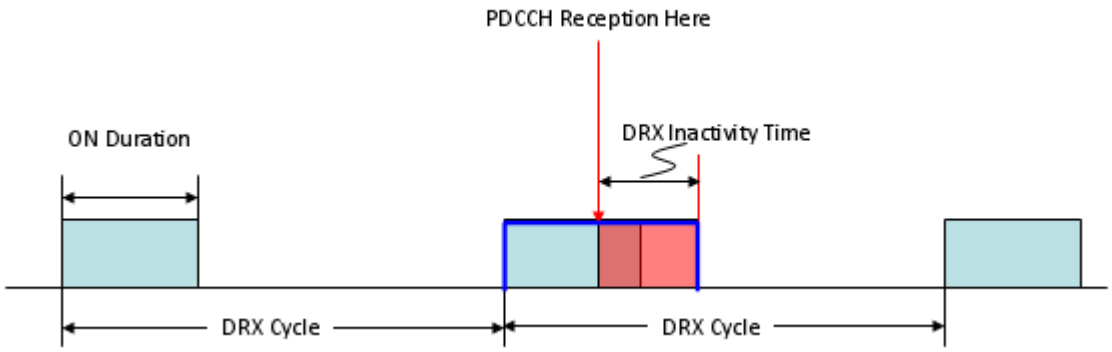
RRC = Radio Resource Control
NAS = Non Access Stratum

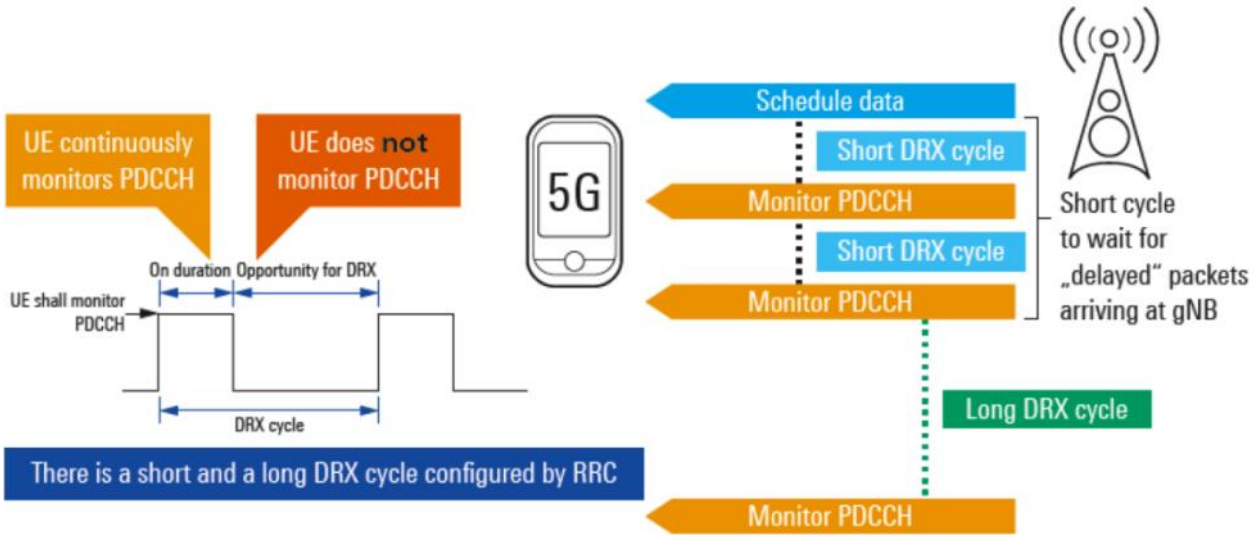
User/Control Plane Entity



* UPF: User Plane Function

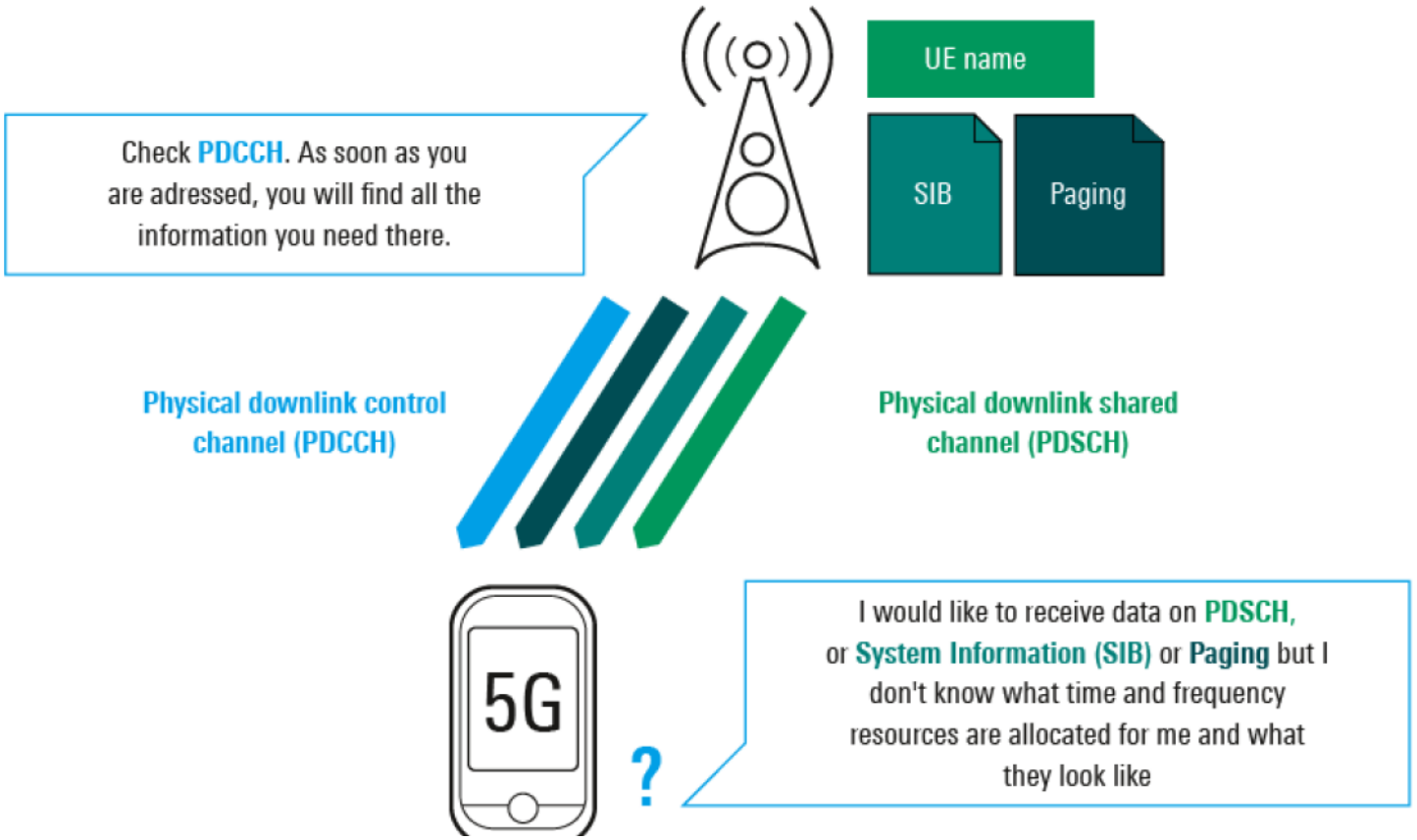
5G DRX Cycle



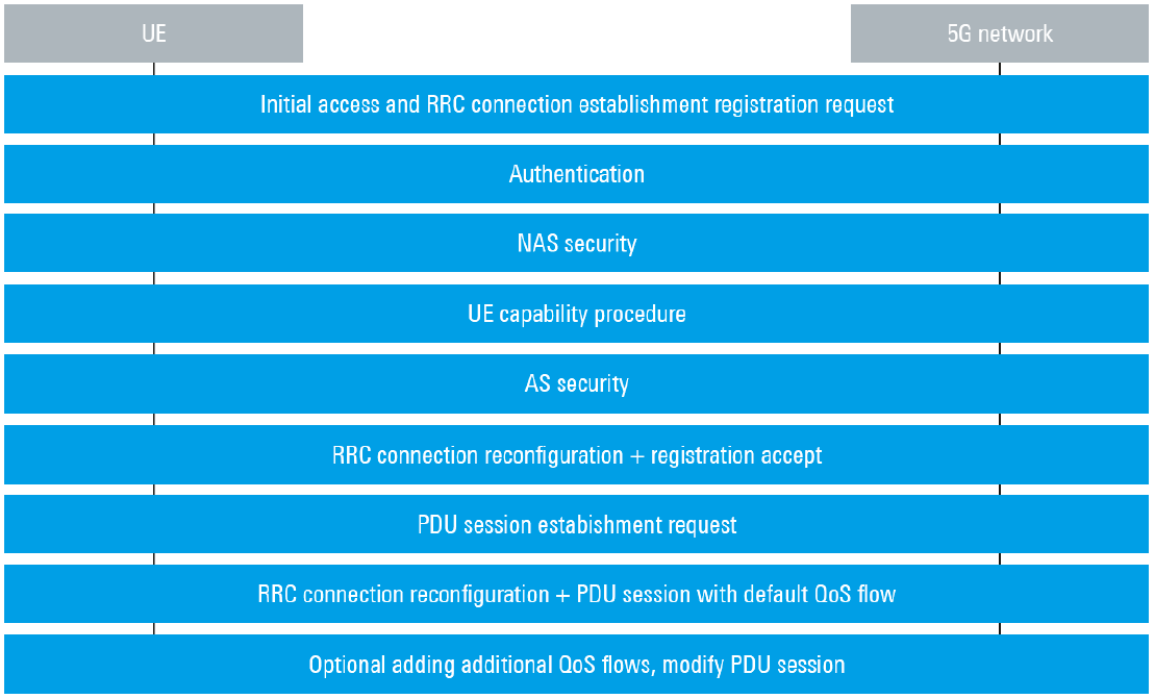


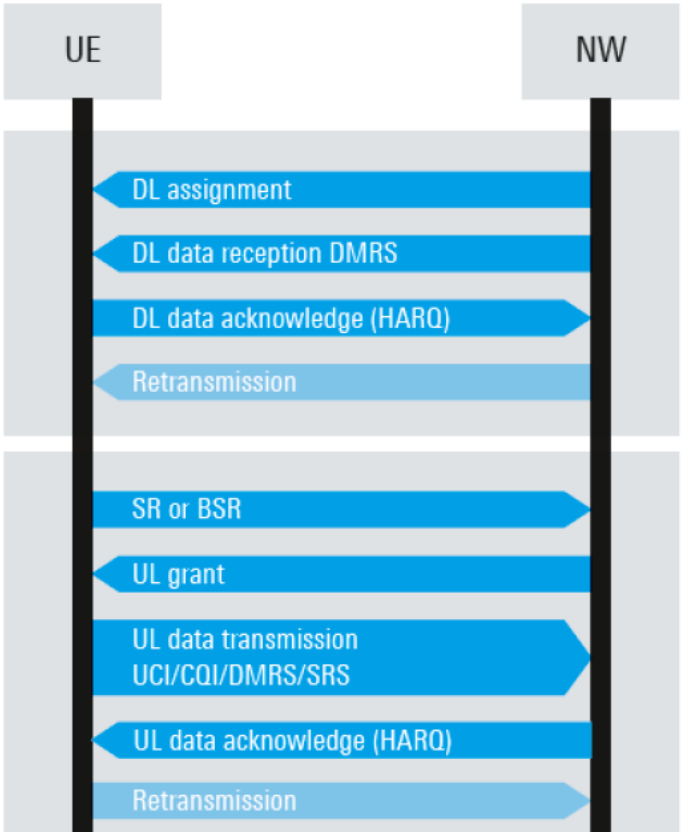
* DRX: Discontinuous Reception
* PDCCH: Physical Downlink Control Channel

Paging Information

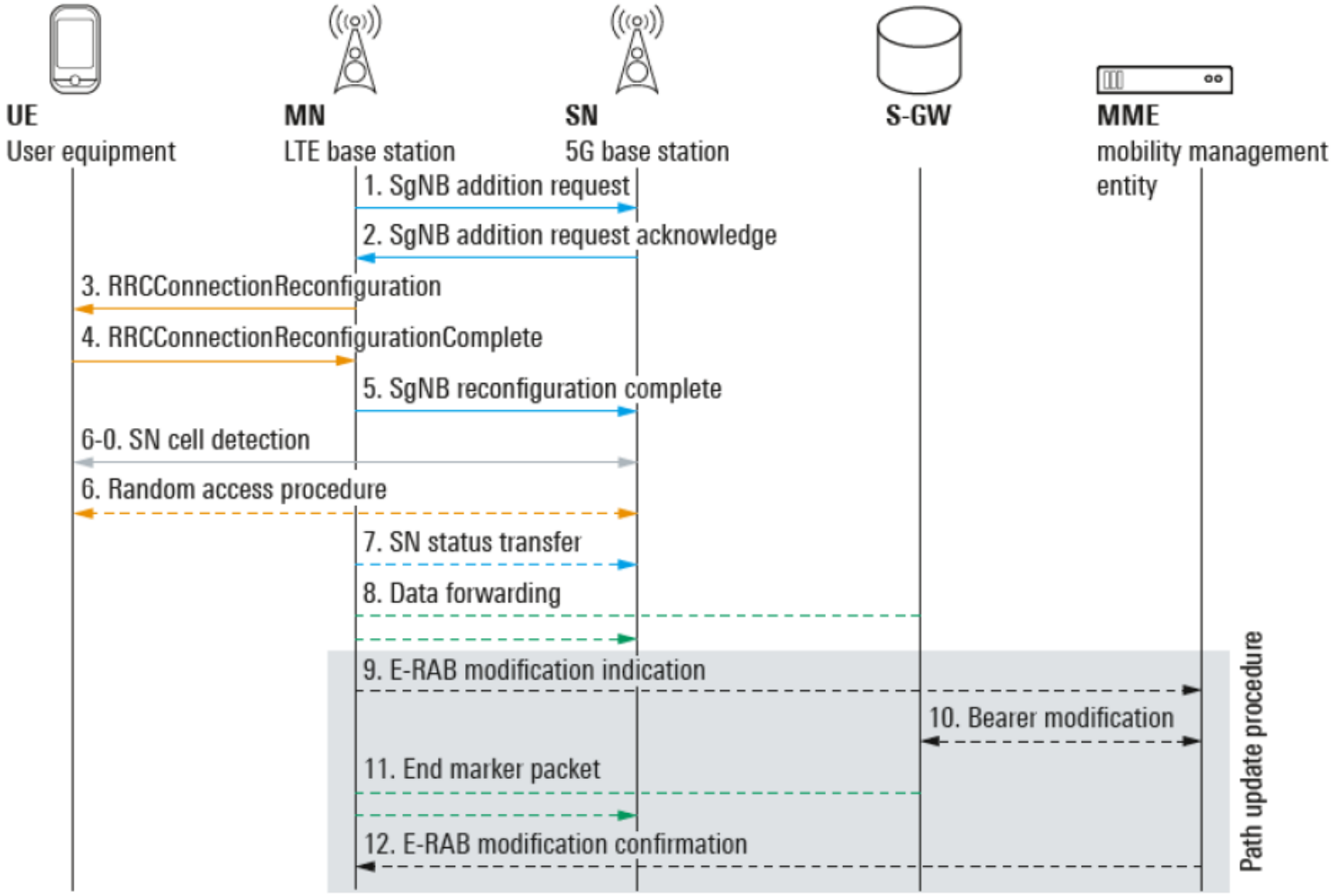


5G SA Mode Call Flow 예

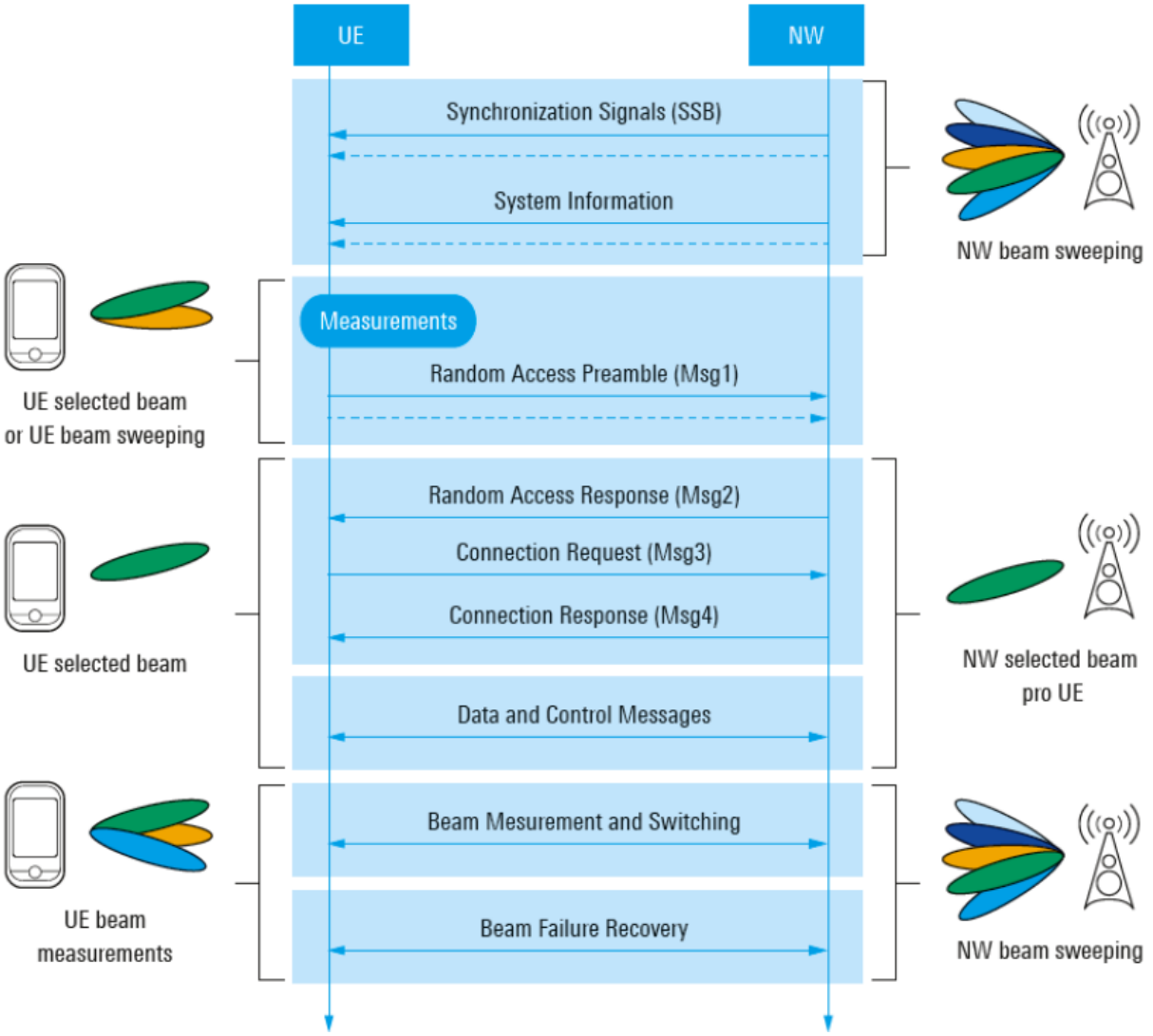




5G NSA Mode Call Flow 예

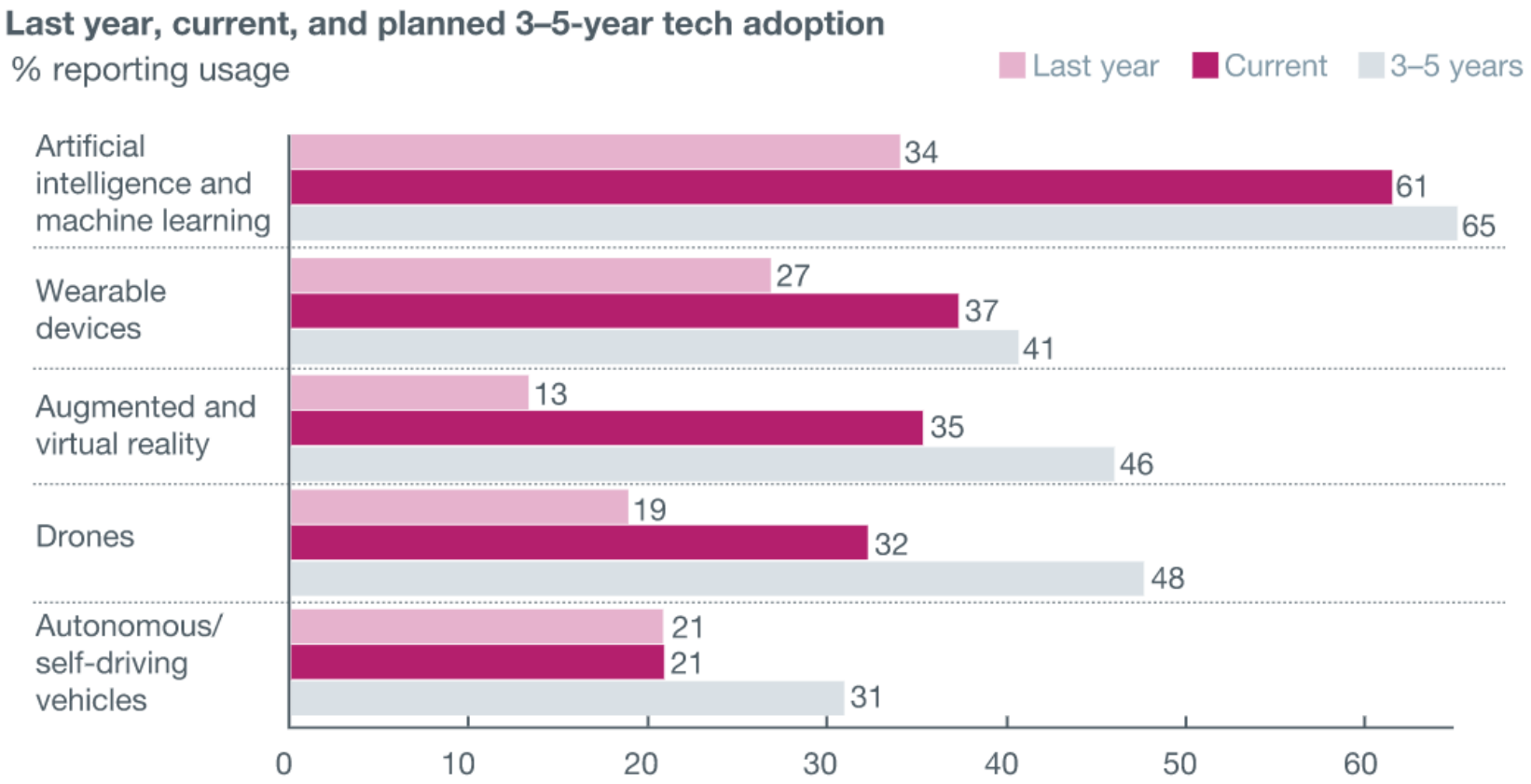


5G Beam Negotiation

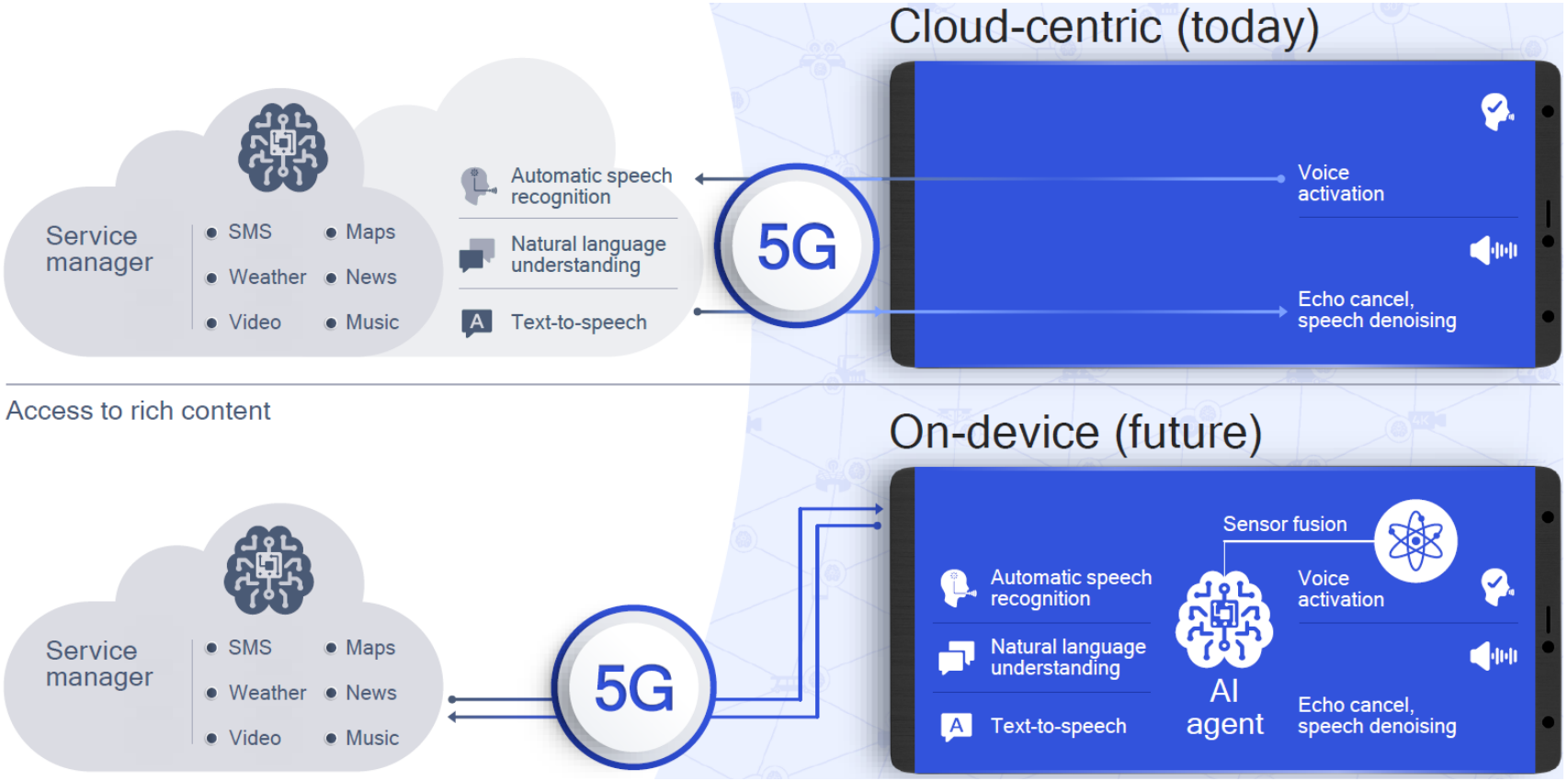


5G with AI

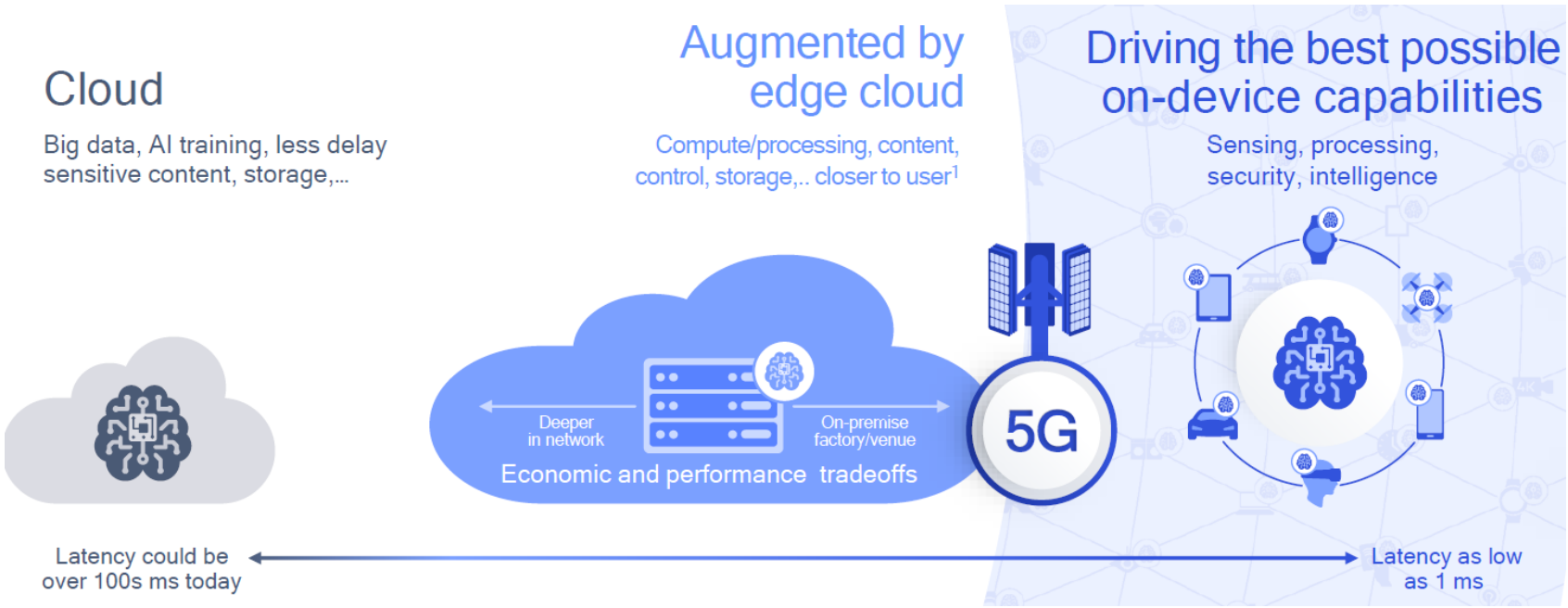
5G에 유망한 적용 기술


Last year, current, and planned 3–5-year tech adoption
% reporting usage
Last year
Current
3–5 years
Artificial intelligence and machine learning
34
61
65
Wearable devices
27
37
41
Augmented and virtual reality
13
35
46
Drones
19
32
48
Autonomous/ self-driving vehicles
21
21
31
0
10
20
30
40
50
60

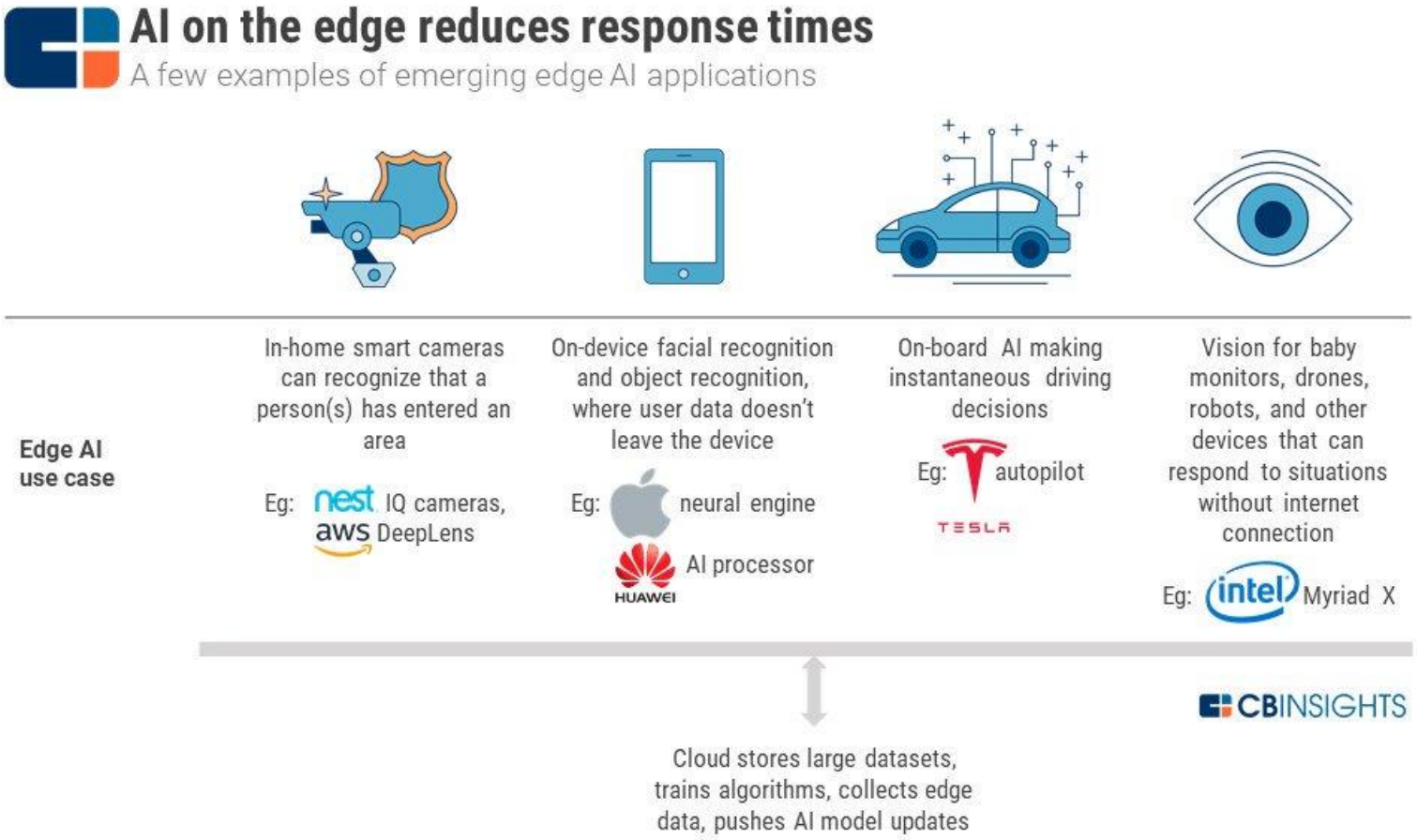
AI on Device(1)



AI on Device(2)



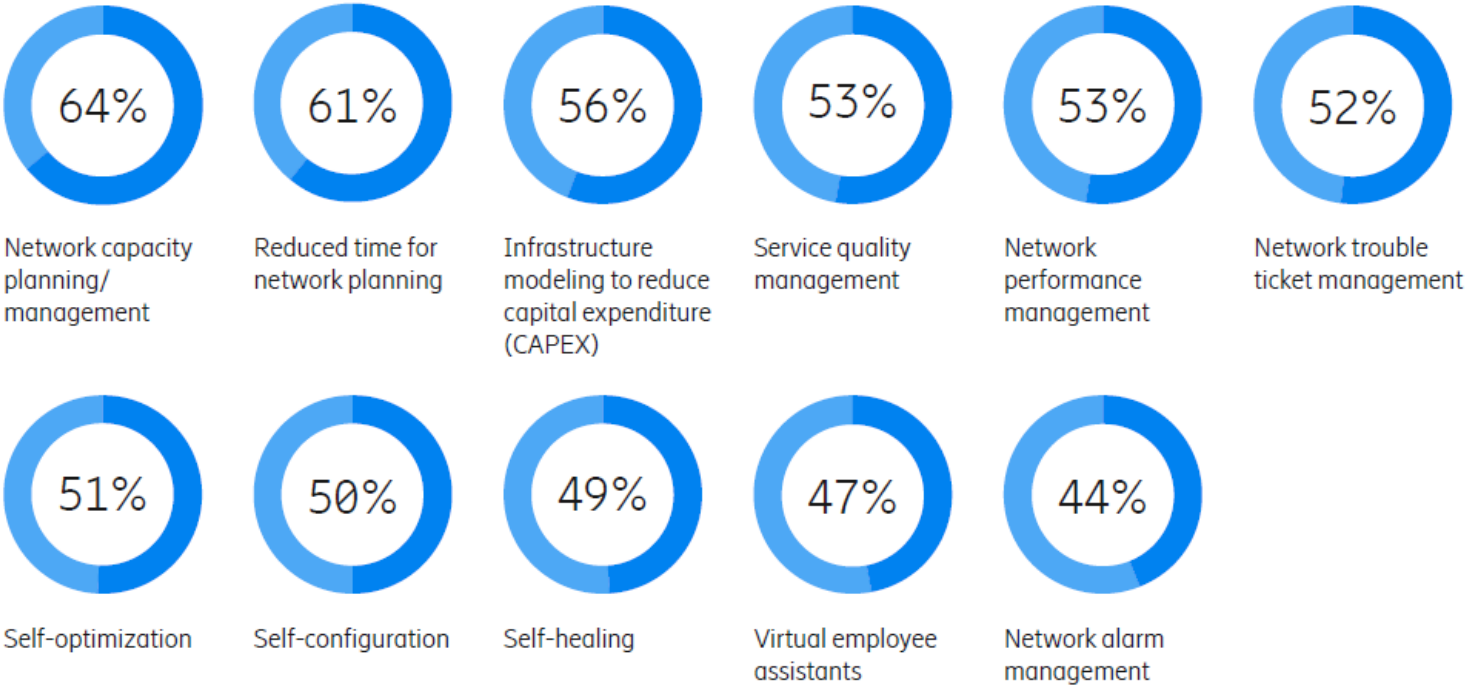
AI on Device(3)



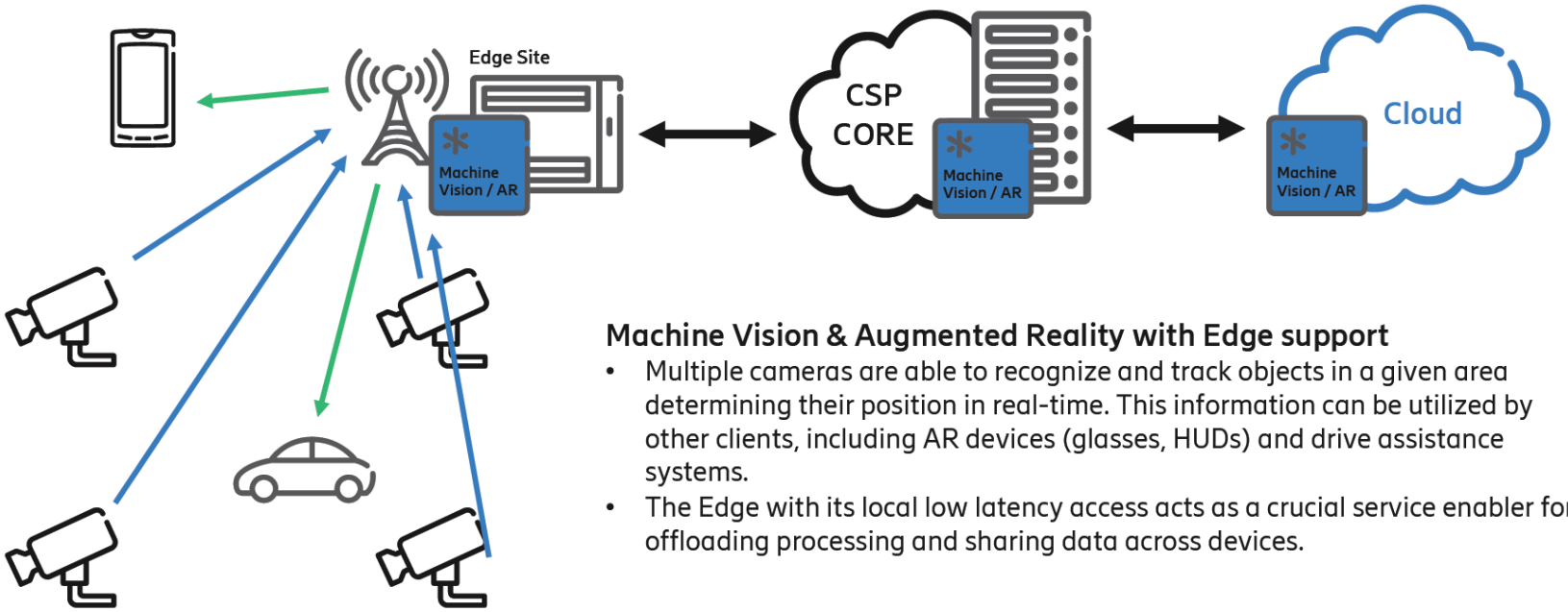
AI on 5G Network(1)

AI on 5G Network(2)

Figure 5: Areas where service providers will be focusing upon adopting AI in their networks



AI on 5G Network(3)



Machine Vision & Augmented Reality with Edge support

- Multiple cameras are able to recognize and track objects in a given area determining their position in real-time. This information can be utilized by other clients, including AR devices (glasses, HUDs) and drive assistance systems.
- The Edge with its local low latency access acts as a crucial service enabler for offloading processing and sharing data across devices.


5G
이동통신 기술과 서비스
5th Generation
Mobile Telecommunication and Services
김현욱 저
동일출판사