Computer Network

Lecture 5
MAC/DLC Part.2

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Contents

- **Cellular Network Overall**
- IMT2020 Overall
- Automotive Applications
- Media Applications
- 5G Technology Characteristics

Cellular Networking Evolution

Wireless Technology View

1G Circuit Voice Channel only

2G + SMS + Circuit Data Channel

3G + High Speed Data Channel (Peak 3.1Mbps 1xEV-DO Rev.A ~ 14.4Mbps HSDPA Rel.5)

4G + Very high speed data channel (Peak 1Gbps)

- Circuit voice channel

3

Cellular Networking Evolution

Wireless Service View

1G Voice

2G + SMS + Small file transfer (Ring bell, wall screen)

3G + MMS + Chat + Web + Medium file transfer (email, app/book/music store, photo)

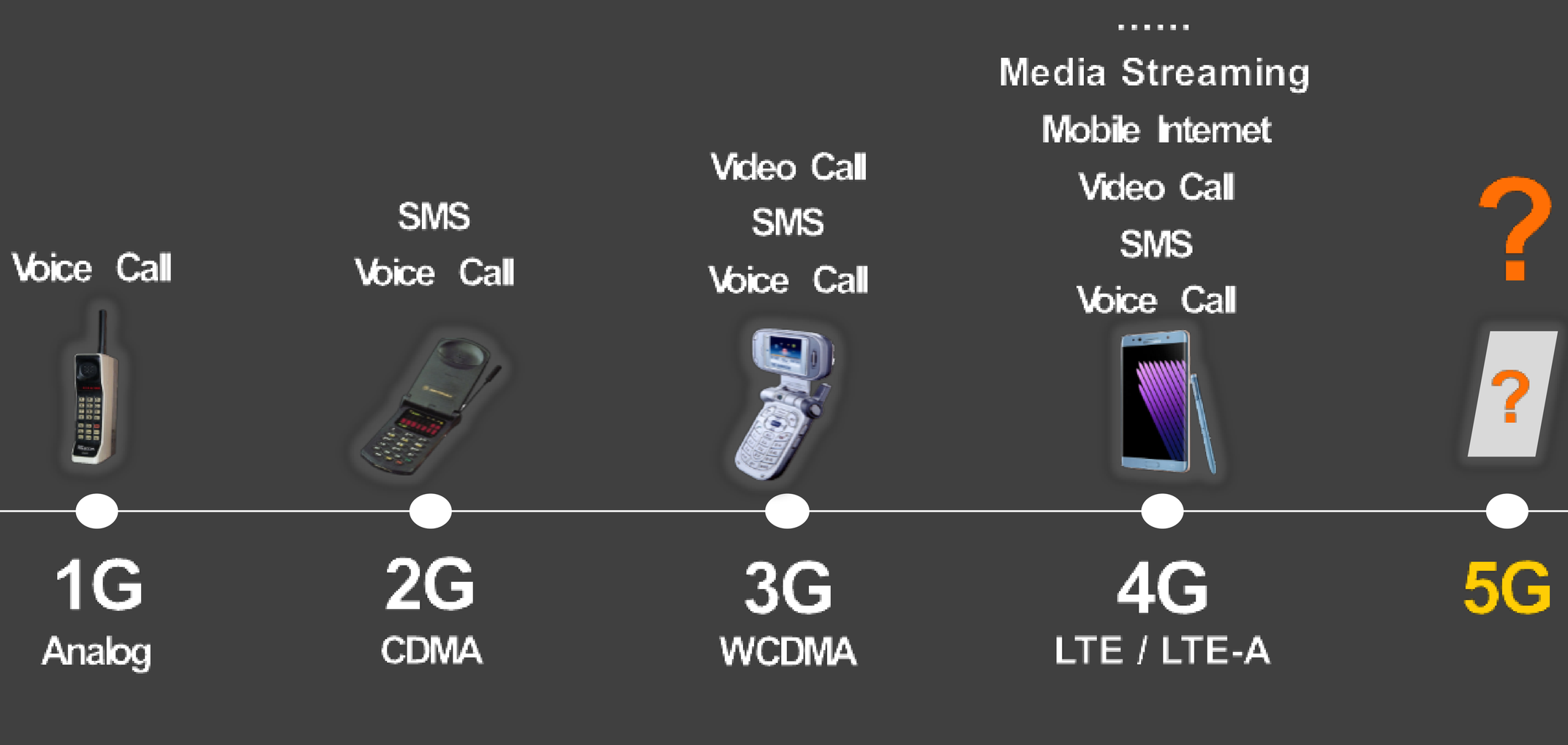
4G + Large file transfer (SD/HD movie?) + Streaming

4

Cellular Phone Evolution

Ref) 5G & New Service

SK telecom



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Cellular Phone Evolution

Reference: http://www.paulsinsight.com/evolution-mobile-phones/

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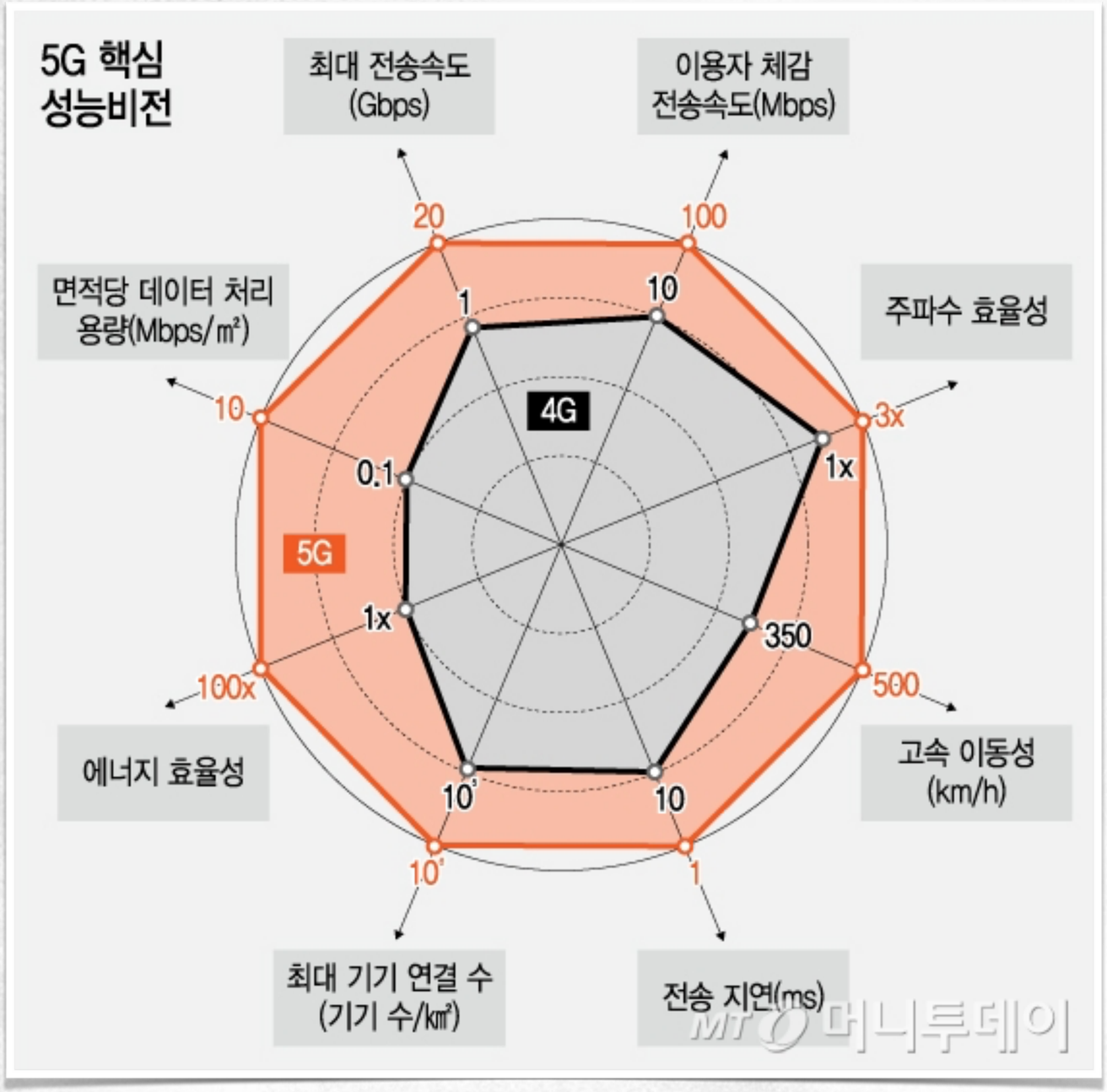
IMT-2020

"5G 이동통신에 대한 ITU의 공식 이름 및 공식 성능 지표"



4G 대비 5G 핵심 성능 비교

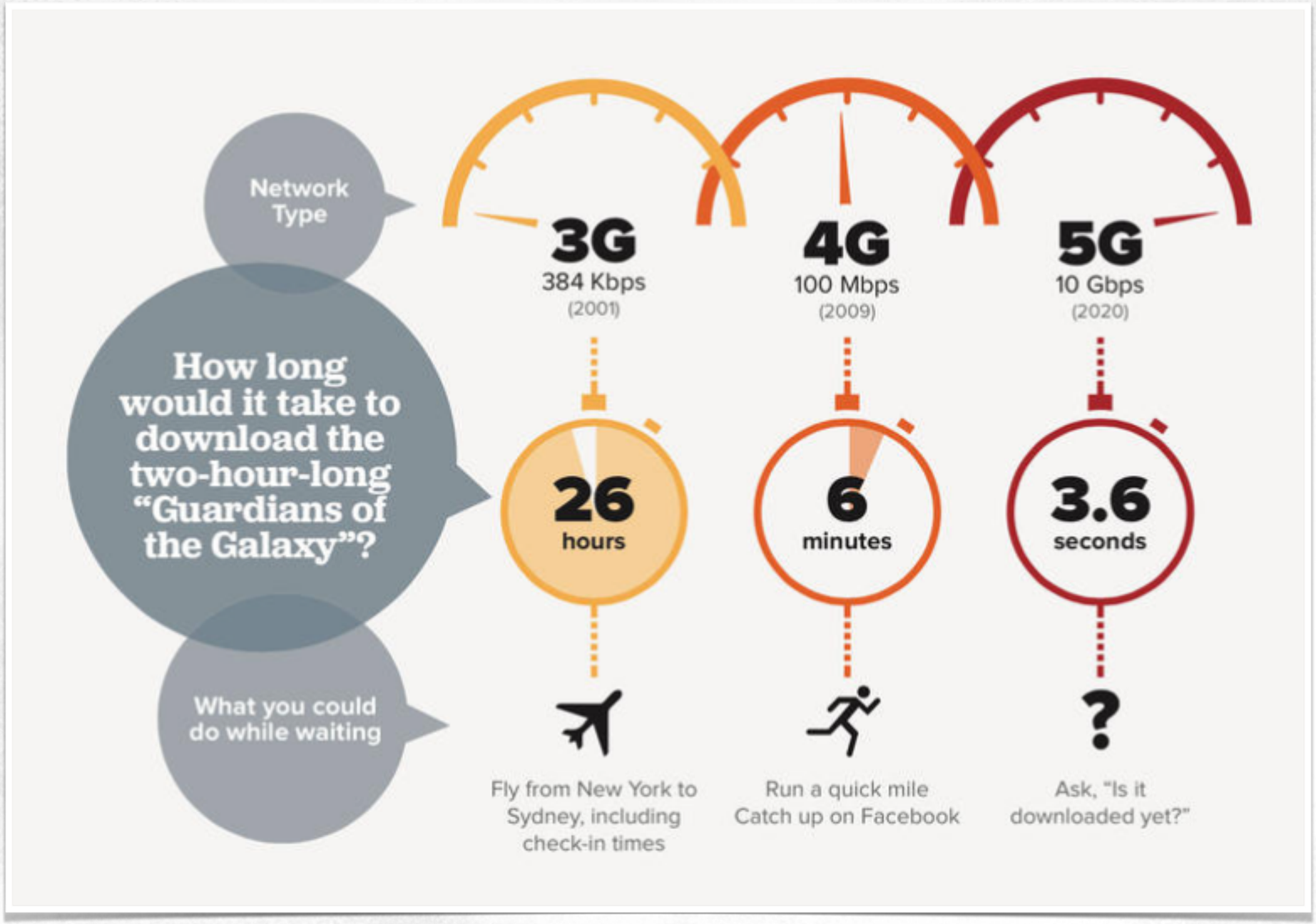
4G(IMT-Advanced)		5G(IMT-2020)
1Gbps	최대 전송속도	20Gbps
10Mbps	이용자 체감 전송속도	100~1000Mbps
	주파수 효율성	4G대비 3배
350㎞/h	고속 이동성	500㎞/h
10ms	전송지연	1ms
10만/㎢	최대 기기 연결수	100만/㎢
	에너지 효율성	4G대비 100배
0.1Mbps/㎡	면적당 데이터 처리용량	10Mbps/㎡

자료 : 미래창조과학부

출처: http://image.fnnews.com/resource/media/image/2015/06/18/201506181728238928_l.jpg
http://i2.media.daumcdn.net/svc/image/U03/news/201506/19/moneytoday/20150619050010032.jpeg

IMT-2020

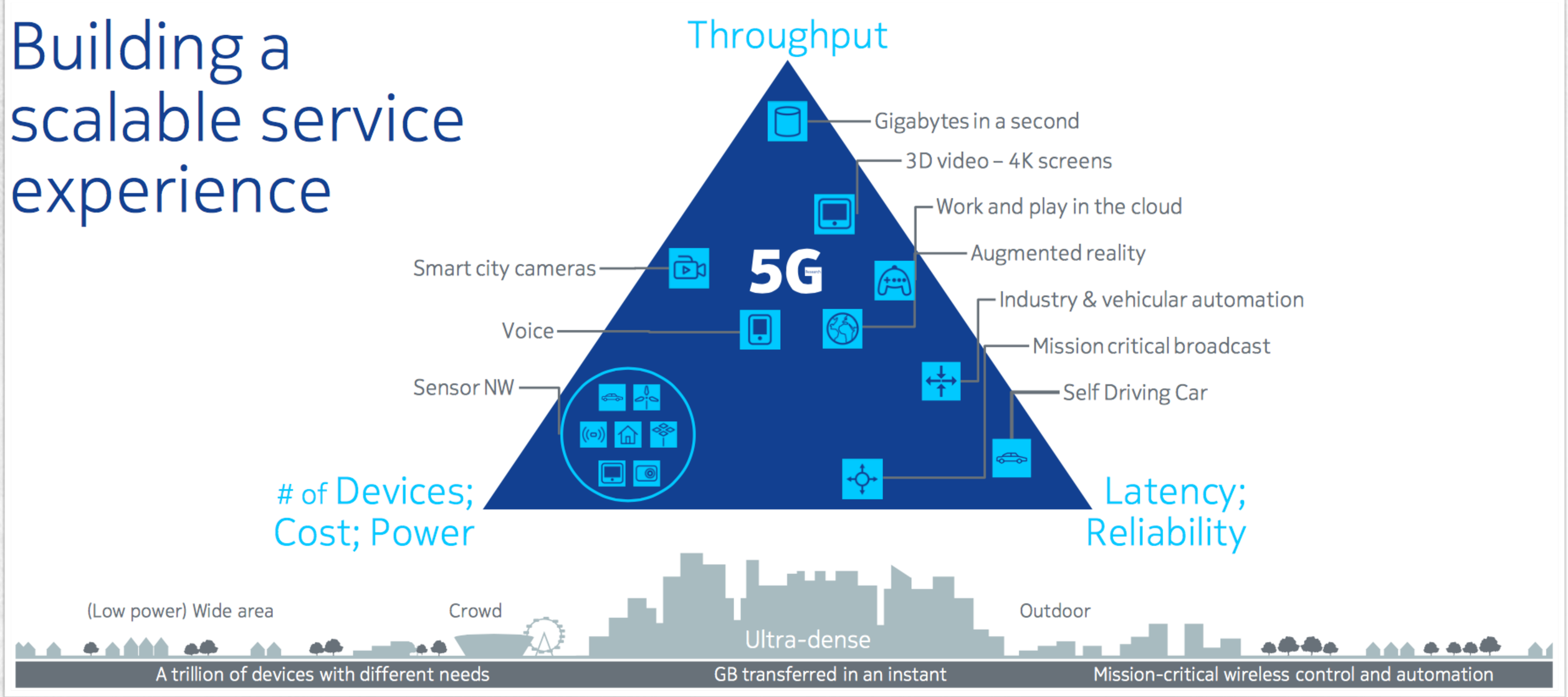
"5G 이동통신에 대한 체감 최고 속도 (현실적인 단말 성능 고려)"



출처: http://www.cnet.com/news/how-5g-will-push-a-supercharged-network-to-your-phone-home-and-car/

Expected 5G Services

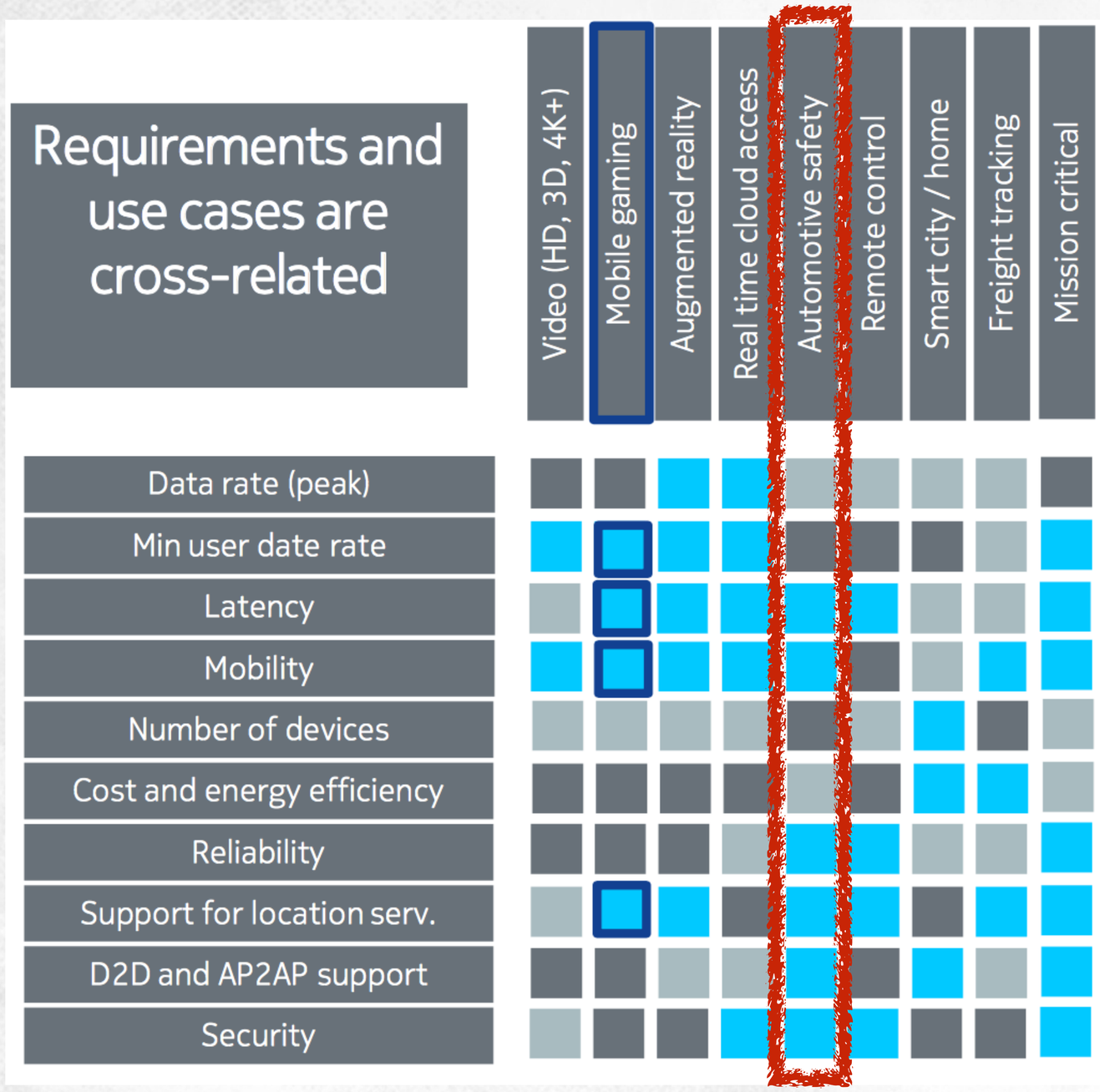
"더 빨라진 인간형 서비스 및 기계들"



출처: http://files-eu.clickdimensions.com/ericssoncom-anlg4/documents/5g_usworkshop_nokia_requirements_final1.pdf

Driving Forces for 5G Networking

"인간형 서비스 보다 더 안정적이고 빨라진 요구사항"



FutureWorks

Example: future gamers will take their connected consoles everywhere and will want to continue perfect HD gaming experience wherever they go

KPI ranges for different use cases		
High	Medium	Low
10 Gbps peak	1 Gbps peak	Best effort
100 Mbps 95% users CDF	10 Mbps 95% users CDF	Best effort
5 ms radio latency 50% users CDF	20 ms radio latency 50% users CDF	Best effort
300 kmph with no service degr.	90 kmph with no service degr.	Best effort
x100 per area (ref 2010)	x10 per area (ref 2010)	Almost organic growth
Cost and battery life essential KPIs	Cost / battery life important	Best effort
Serv. supported in 99,99966% cases	Service supported in 95% cases	Best effort
Location info essential	Location info useful	Location info rarely relevant
Very diverse comm. scenarios	Somehow diverse comm. scenarios	Mostly traditional UL/DL cases
Very high security level required	Increased security important	Best effort

출처: http://files-eu.clickdimensions.com/ericssoncom-anlg4/documents/5g_usworkshop_nokia_requirements_final1.pdf

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5G into Automotive Industry

Rapid Growth in Automotive Processing and Software

Electronic Control Units (ECU) shift to central domain controllers over in-car networks

In-vehicle Infotainment
Audio, Visual, Maps, Traffic, Mobile phone integration, SIM, Toll payment, Google services, seat back display

Gateways
GSM 3G 4G LTE, Bluetooth®, WiFi, CAN, LIN, Flexray, TTP

Body Electronics
Heating, Ventilation, AC, Lighting, Electric seat, Windows, Mirrors, Cameras, Seat belt, Air bag, Comfort, Convenience

→ **Body control**

Dashboard
Instrument display surface, Head-up display, IVI display

Hybrid Electric Vehicle
Battery management
Motor control

→ **Powertrain**

Car-to-car
Vehicle-to-Vehicle
Vehicle-to-Infrastructure

Connected Car
Car-to-car, Crash alert, Service, Maps
Insurers' black box

→ **Chassis / Safety**

Advanced Driver Assistance System
Radar/image processing, Collision avoidance, Emergency braking, Adaptive cruise control, Lane departure warning, Parking assistance

Powertrain
Engine Control Unit, Sensors, Gearbox

Chassis
Braking, Steering, Stability, ABS, VSC, EPS

→ **IVI / Connectivity**

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ARM

5G into Automotive Industry

What is our (multitenant) 5G network and services vision?

- *1000x higher wireless area capacity and 10G true immersive experience*
- *100 billions of connections and 5x lower E2E latency (1ms target)*
- *90% energy saving per provided service*

1) FULL Immersive Experience
2) ANYTHING as a Service

80Gb/s
E-Band link
50Gb/s Macro
100Gb/s Micro
Tera-Cell
10Gb/s link speed
Intelligence
"Edge"
100T OXC
Bearer Graph
Ephemeral Networks
[KIT]
V2I
Cloudlet
[Amazon]
[iCUB, IIT, Italy]
[safetybasement.com]
V2V
[Google]
V2D
David Soldani, Huawei, 5GIA Board Member
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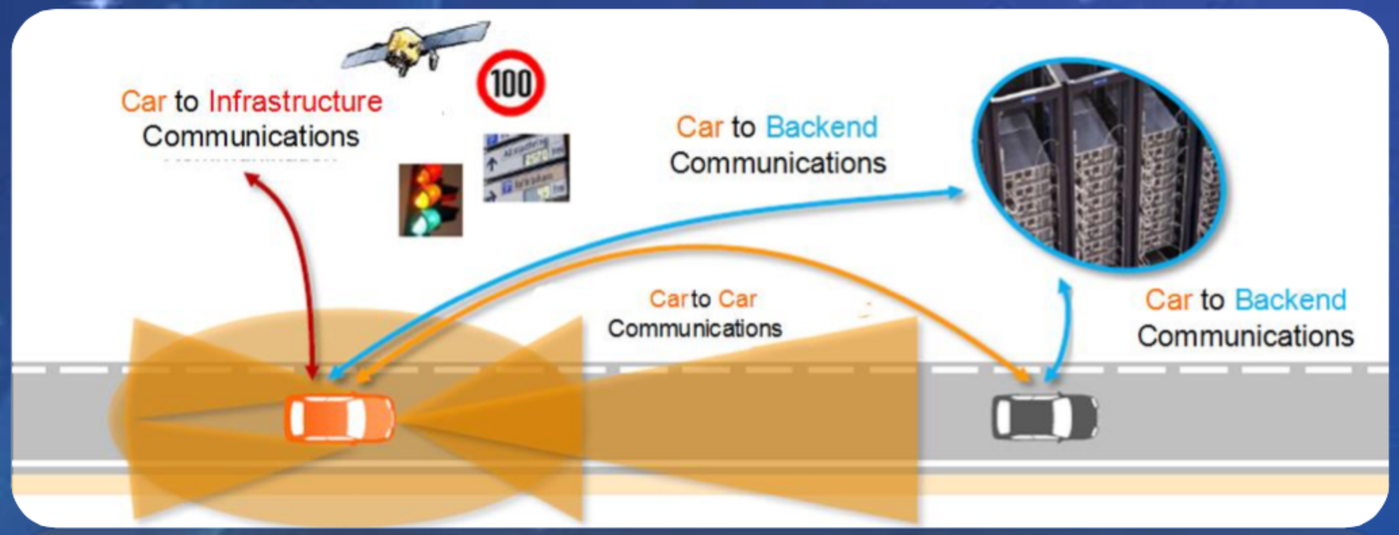
출처: http://www.ieeevtc.org/conf-admin/vtc2015spring/5.pdf

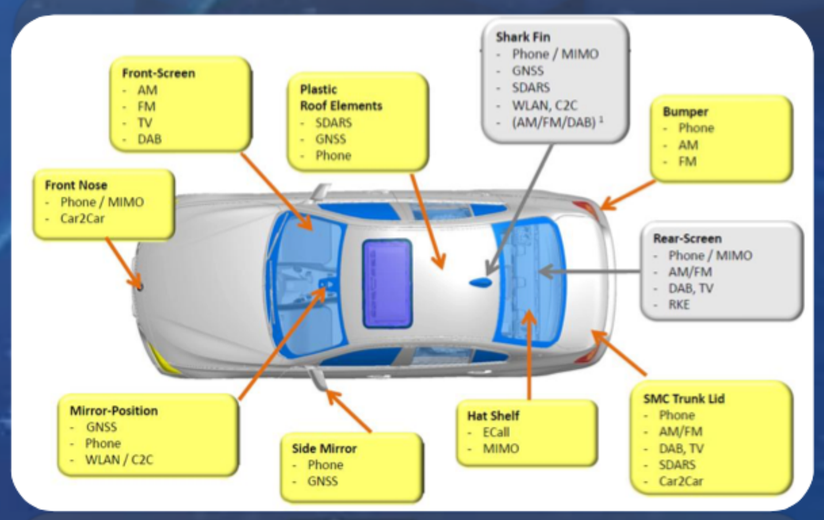
5G into Automotive Industry

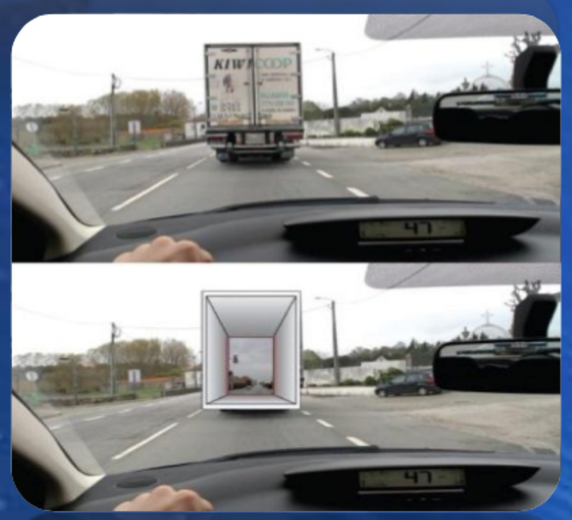
Example: Future Car Communications

2

➔ *New Antenna Concepts for MIMO, Integration of 11p and LTE/5G, Mobile Edge Computing*







[Kathrein Automotive]

Communication requirements

- Better connection than smart phone
- Reliable and low latency for future advanced driver assistant systems (ADAS) and autonomous driving (AD)
- High data volumes (>200Mb/s) at low latencies for future cooperative automatic driving functions (V2V)
- Support performance up to maximum speed (500km/h relative)
- Any network operator, regardless vehicle occupants' contract (safety information)

[Markus Dillinger, Huawei]

David Soldani, Huawei, 5GIA Board Member

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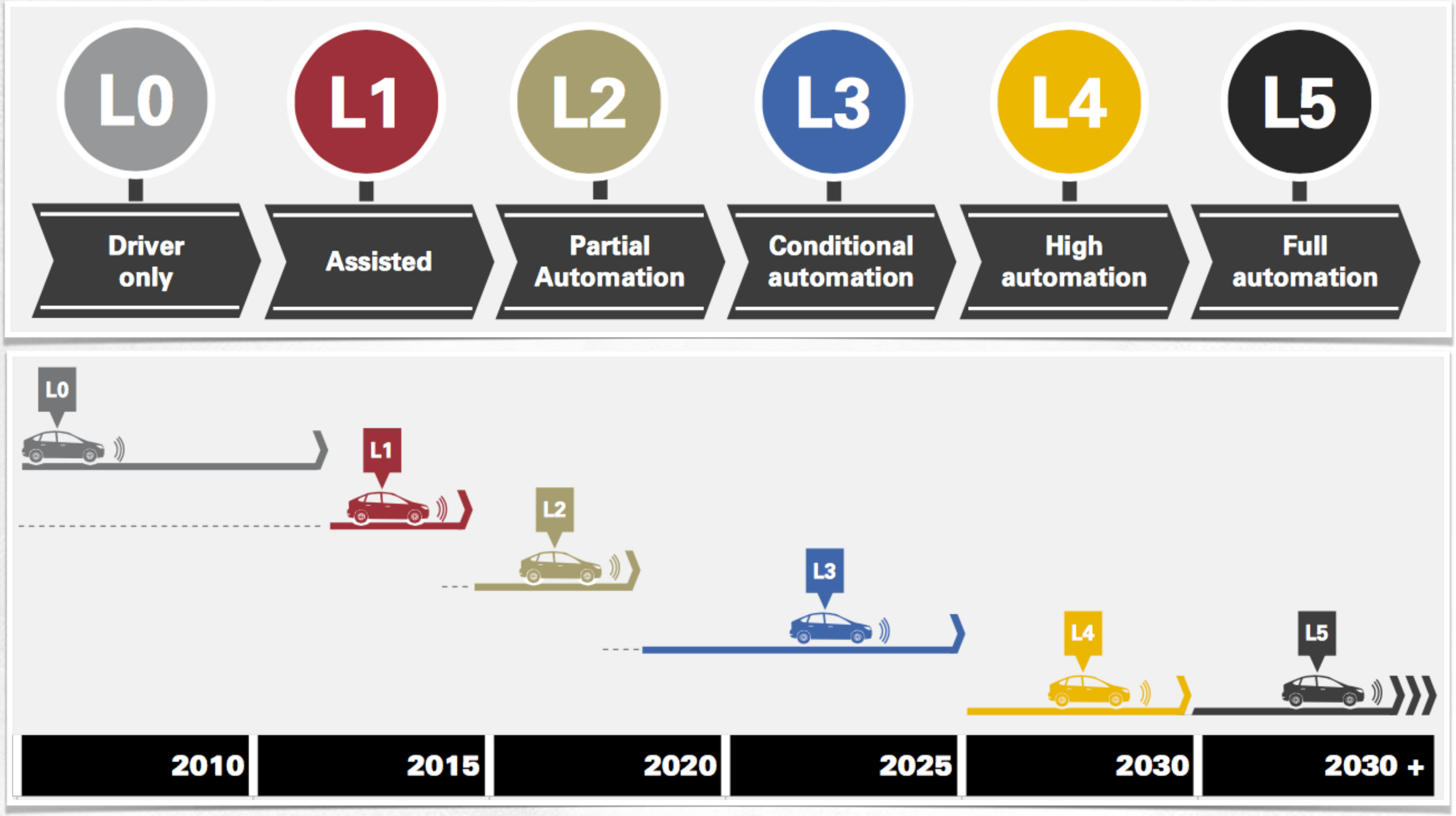
출처: http://www.ieeevtc.org/conf-admin/vtc2015spring/5.pdf

Automotive & 5G/6G?

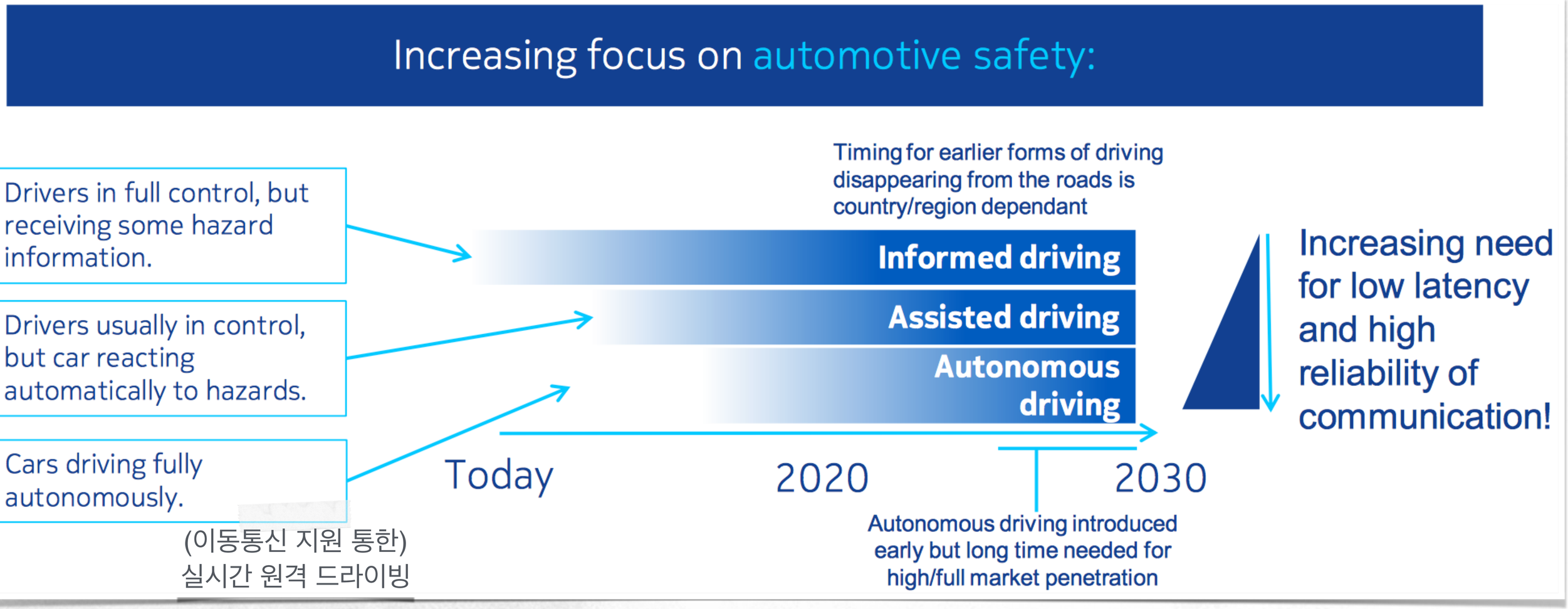
"5G(2020년~)과 6G(2030년~)에 무엇이 현실적으로 가능할까?"



출처: https://www.kpmg.com/BR/en/Estudos_Analises/artigosepublicacoes/Documents/Industrias/Connected-Autonomous-Vehicles-Study.pdf

Automotive & 5G/6G?

"5G(2020년~)과 6G(2030년~)에 무엇이 현실적으로 가능할까?"



(이동통신 지원 통한)
실시간 원격 드라이빙

출처: http://files-eu.clickdimensions.com/ericssoncom-anlg4/documents/5g_usworkshop_nokia_requirements_final1.pdf

Automotive & 5G/6G?

"5G(2020년~)과 6G(2030년~)에 무엇이 현실적으로 가능할까?"

With the autonomous driving the communication among vehicles and between vehicles and infrastructure needs to be fast and reliable as it will be used e.g. for propagating warning messages. Accurate positioning and high availability of the communication both in time and space are also needed.

E2E LATENCY below 5ms

Application level delay between transmitter and receiver. This very low E2E latency is possible if the ends are close to one another (e.g. direct device to device)

RELIABILITY six-sigma level or better

defined as the probability of delivery within the QoS requirements (including required latency). High reliability with low latency is only possible for small packets of data.

AVAILABILITY aiming for 100%

The vehicle communication service should be ubiquitously available. This is not equivalent to 100% mobile coverage as the car to car communication can also be autonomous device to device.

POSITIONING ACCURACY ~0,5m

This very exact positioning may be relative.

출처: http://files-eu.clickdimensions.com/ericssoncom-anlg4/documents/5g_usworkshop_nokia_requirements_final1.pdf

Automotive Software

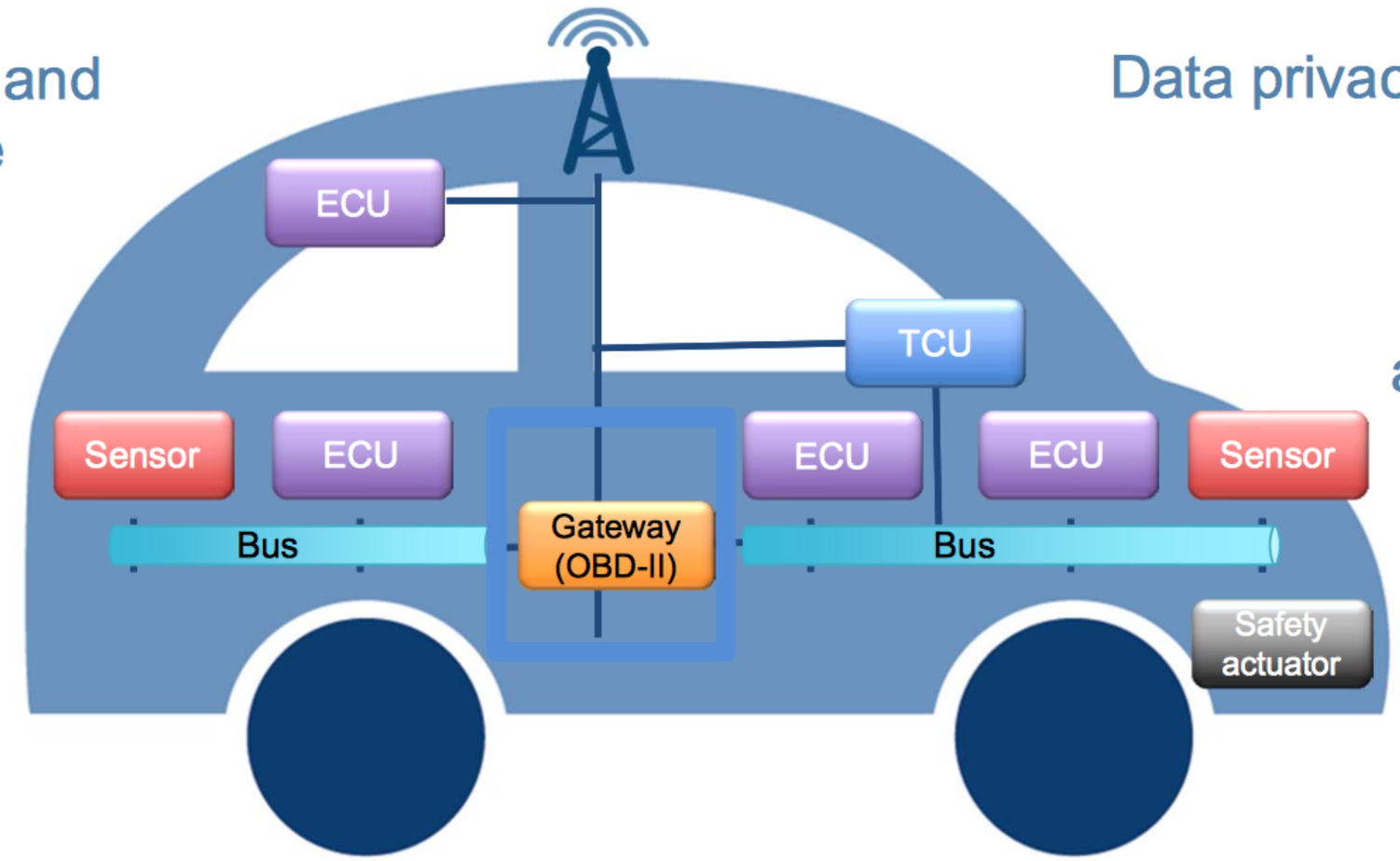
“Ericsson’s Expectation”

Security and Connectivity Needs in the Car

A VARIETY OF SENSORS AND ELECTRONIC CONTROL UNITS NEED SECURITY

Secure OS and firmware

Data privacy protection



Application security

Strong authentication

Trusted identity

Access control

Giesecke & Devrient

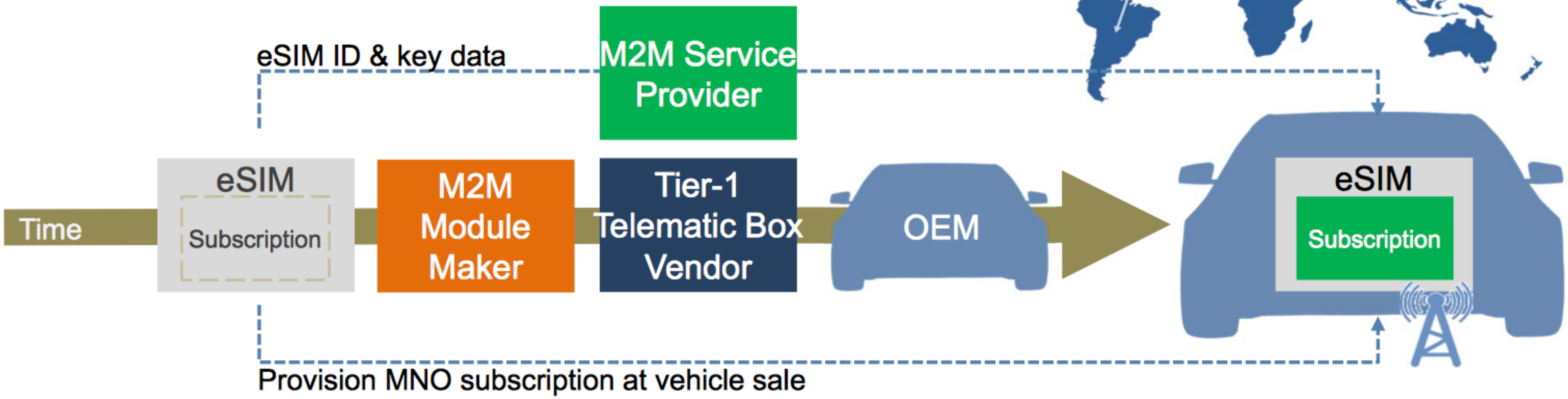
출처: http://www.gi-de.com/gd_media/media/documents/complementary_material/mobile_security_2/mwc2015/MOVE_Connected_Car_and_eCall.pdf

Automotive Software

“Ericsson’s Expectation”

How to Build a Car that Connects at Every Shipping Destination

Connected Car
powered by subscription management



Giesecke & Devrient

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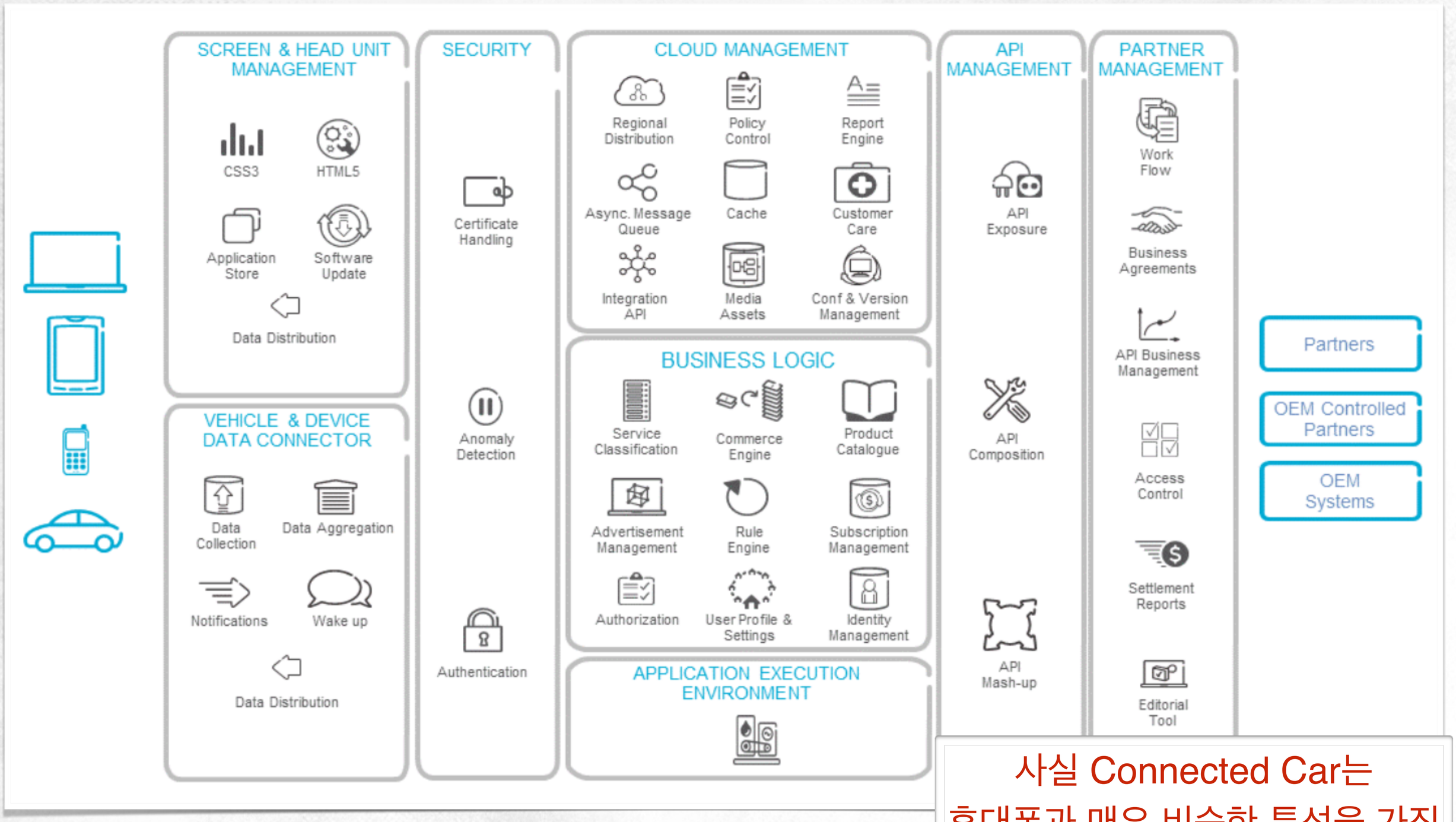
Automotive Software

“Ericsson’s Expectation”

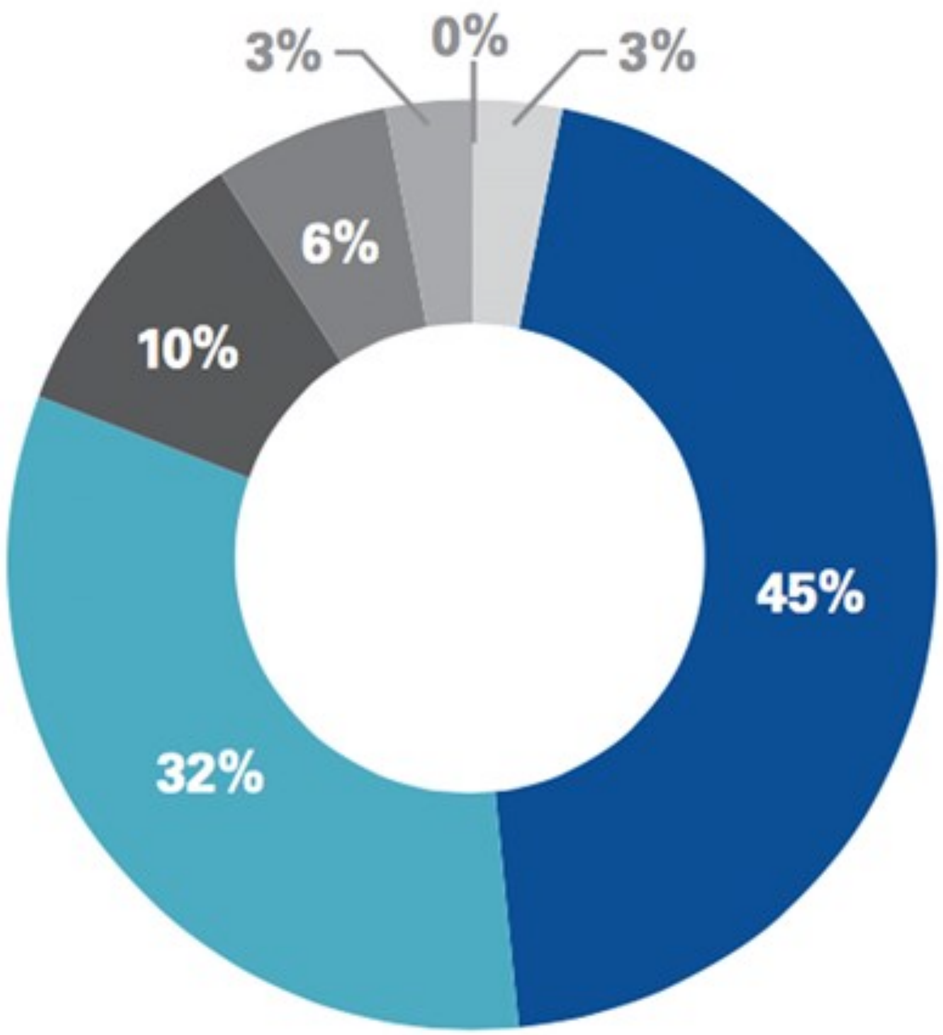


사실 Connected Car는
휴대폰과 매우 비슷한 특성을 가짐

출처: http://www.ericsson.com/industry-transformation/wp-content/uploads/sites/7/2014/09/Connected-Vehicle-Cloud-RevB2.pdf

Automotive Software

“Market’s Expectation”



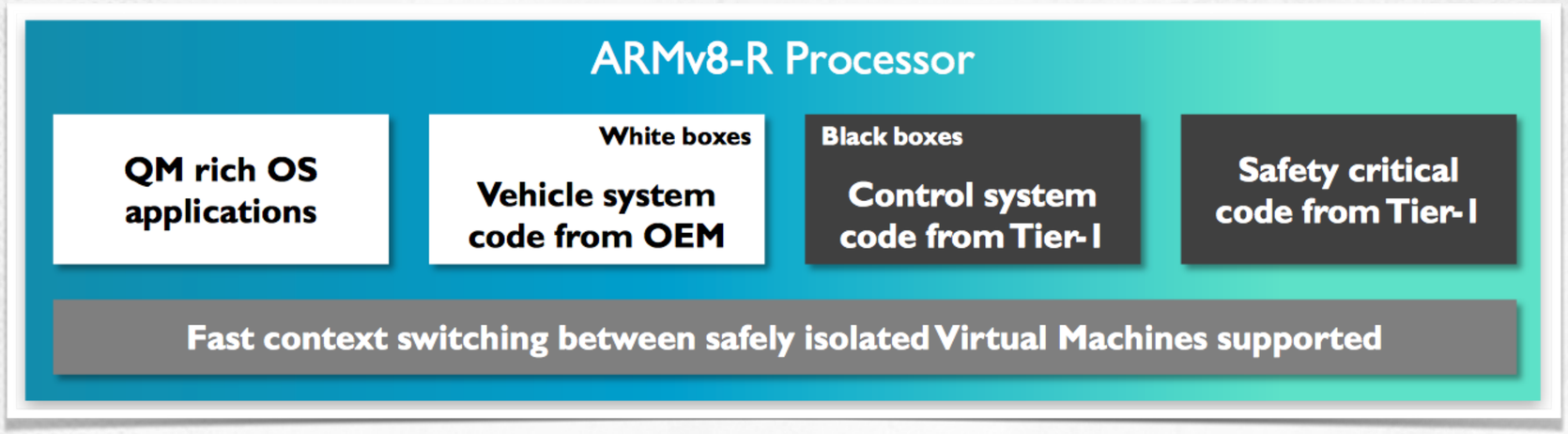
Who will become the leading players in the driverless vehicle sector?

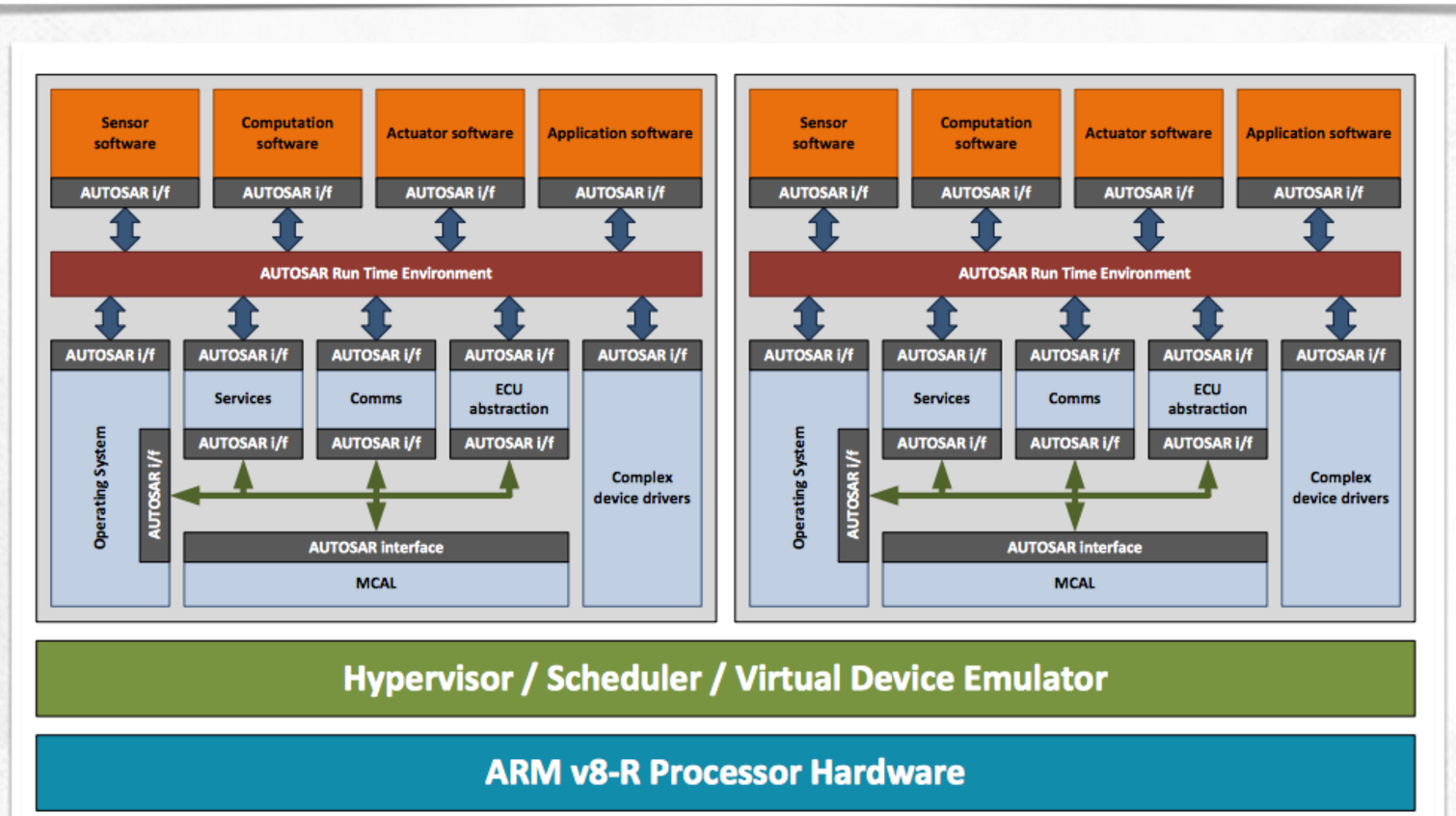
- Established technology firms (Google, Intel, etc.)
- Original equipment manufacturers (OEMs) (Ford, Mercedes Benz, etc.)
- Start-up companies
- Capital providers (Venture capital, private equity, and other investment firms such as Andreessen Horowitz, Kleiner Perkins, etc.)
- Universities and research institutions (MIT, Stanford, etc.)

출처: http://community.arm.com/servlet/JiveServlet/previewBody/9723-102-1-18779/ARM%20TechSymp%20Paris%202014%20-%20The%20ARM%20Connected%20Car.pdf

Automotive Software Virtualization

"ARM Approach"

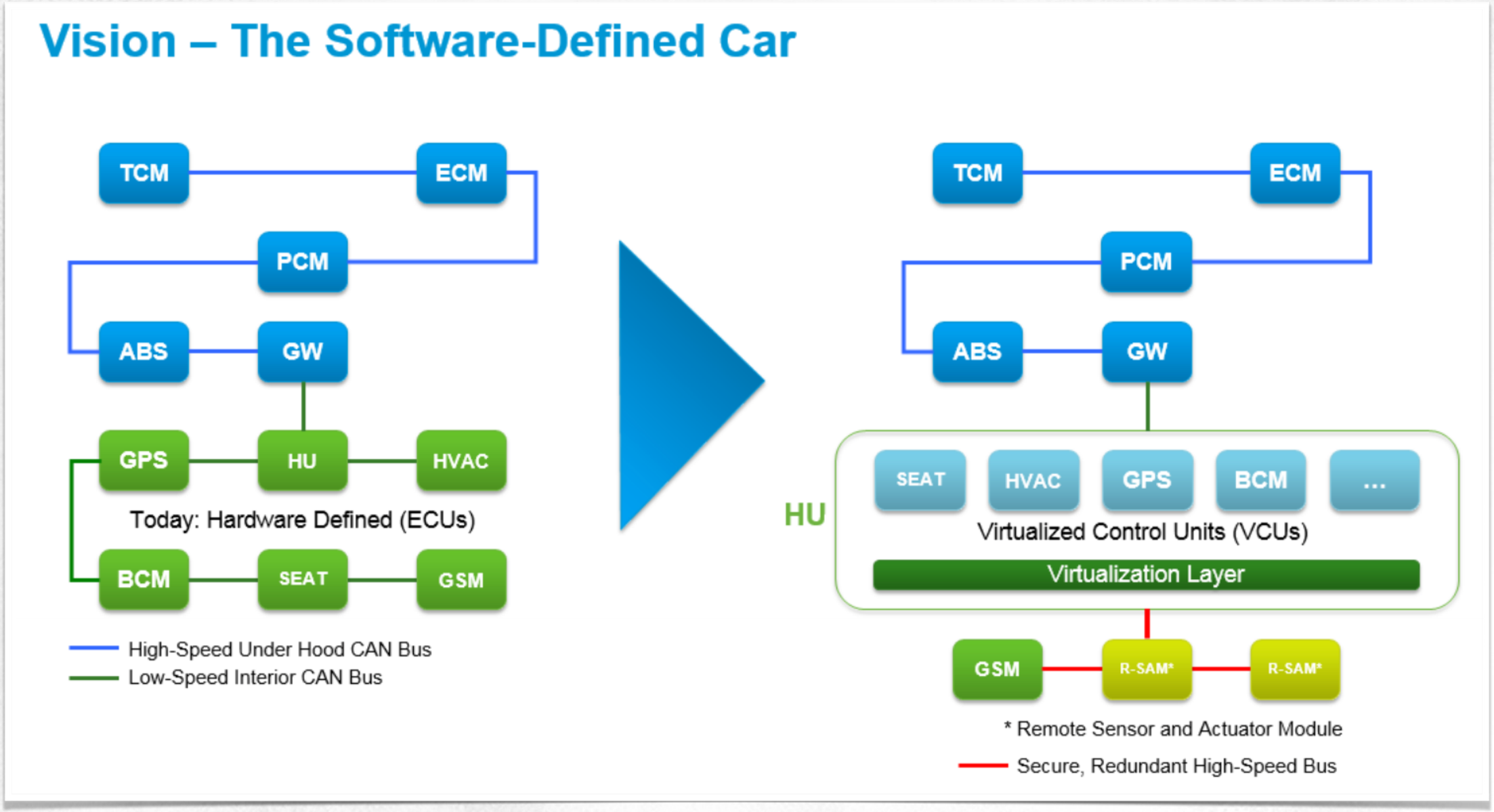




출처: http://community.arm.com/servlet/JiveServlet/previewBody/9723-102-1-18779/ARM%20TechSymp%20Paris%202014%20-%20The%20ARM%20Connected%20Car.pdf

Automotive Software Virtualization

"VMware Approach"



출처: http://community.arm.com/servlet/JiveServlet/previewBody/9723-102-1-18779/ARM%20TechSymp%20Paris%202014%20-%20The%20ARM%20Connected%20Car.pdf

5G into Automotive Industry

"자동차에 필요한 기술을 이동통신에 반영하는 노력 필요"

METIS CONSORTIUM

5 VENDORS

Alcatel-Lucent, Ericsson, Huawei,
Nokia, NSN

5 OPERATORS

Deutsche Telekom, DOCOMO,
Orange, Telecom Italia, Telefonica

13 ACADEMIC ORGANIZATIONS

AAU, Aalto, CTH, HHI, KTH, NKUA,
Oulu, PUT, RWTH, TB, UB, UKL, UPV

AUTOMOTIVE INDUSTRY

BMW

출처: http://www.slideshare.net/Ericsson/m2m-deployments-in-sdn-enabled-ipv6-networks

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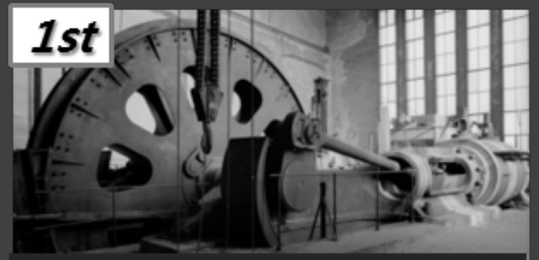
The Fourth Industrial Revolution

SK telecom

Industrialization → **Digitalization → Digital Transformation**



Mechanization (1784~)

- Mechanical production
- Steam Engine, Spinning Machine
- Railway

Manufacturing (1870~)

- Division of Labor
- Electrification
- Mass Production

Information Revolution (1969~)

- Mainframe, PC
- Internet
- Moore's Law

The Fourth Industrial Revolution (2016~)

- Unprecedented changes in terms of velocity, scope
- Impact on the essence of human experience
- AI, IoT, Big Data, CPS Cyber Physical System
- Tech Convergence

2

Digital Transformation

Digitization → **Digitalization** → **Digital Transformation**

"Conversion" | *"Process"* | *"Effect"*

- Analog → Digital
- Industry-wide digitization of data

- 'Process' of digitized information
- IoT, Industry 4.0, Big Data, and Blockchain

- Overall changes followed by digitalization
- Game-changing opportunities in business model, socioeconomic structure, legal/policy standards, and cultural barrier

Transformation involves making fundamental changes in business

New and essential types of innovation through Digital Processing Technologies

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Changes in New Media

1) Various Formats/Ultra High Quality
2) Media Creation and Consumption
3) Adoption of Artificial Intelligence

Reference: 5G & Future Media, SK Telecom

1) Various Formats/Ultra High Quality

Stereoscopic

360 VR

Telepresence

8K+

HDR

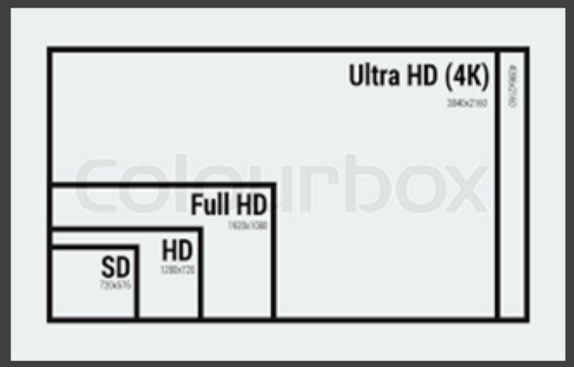
90+ fps

New Media Services & Formats

For Real VR

To Provide **Retina Experience**

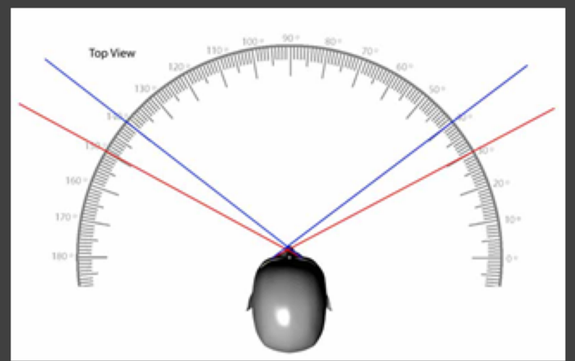
Resolution



1200X1080

5073X5707

Field of View



110°

200°

Motion to Photon Latency

130~1,118ms

20ms

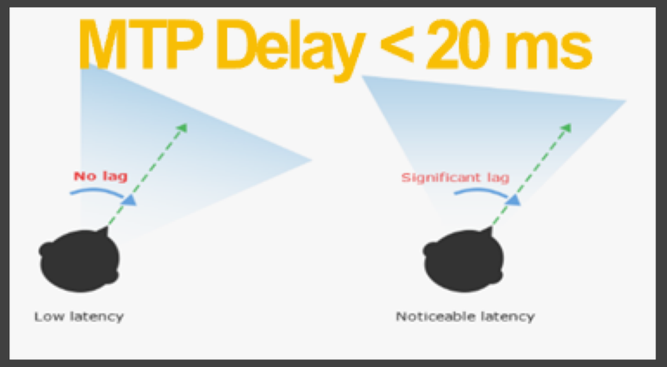
Reference: 5G & Future Media, SK Telecom

5G for VR

Latency

Motion Sickness

Motion to Photon(MTP) Latency



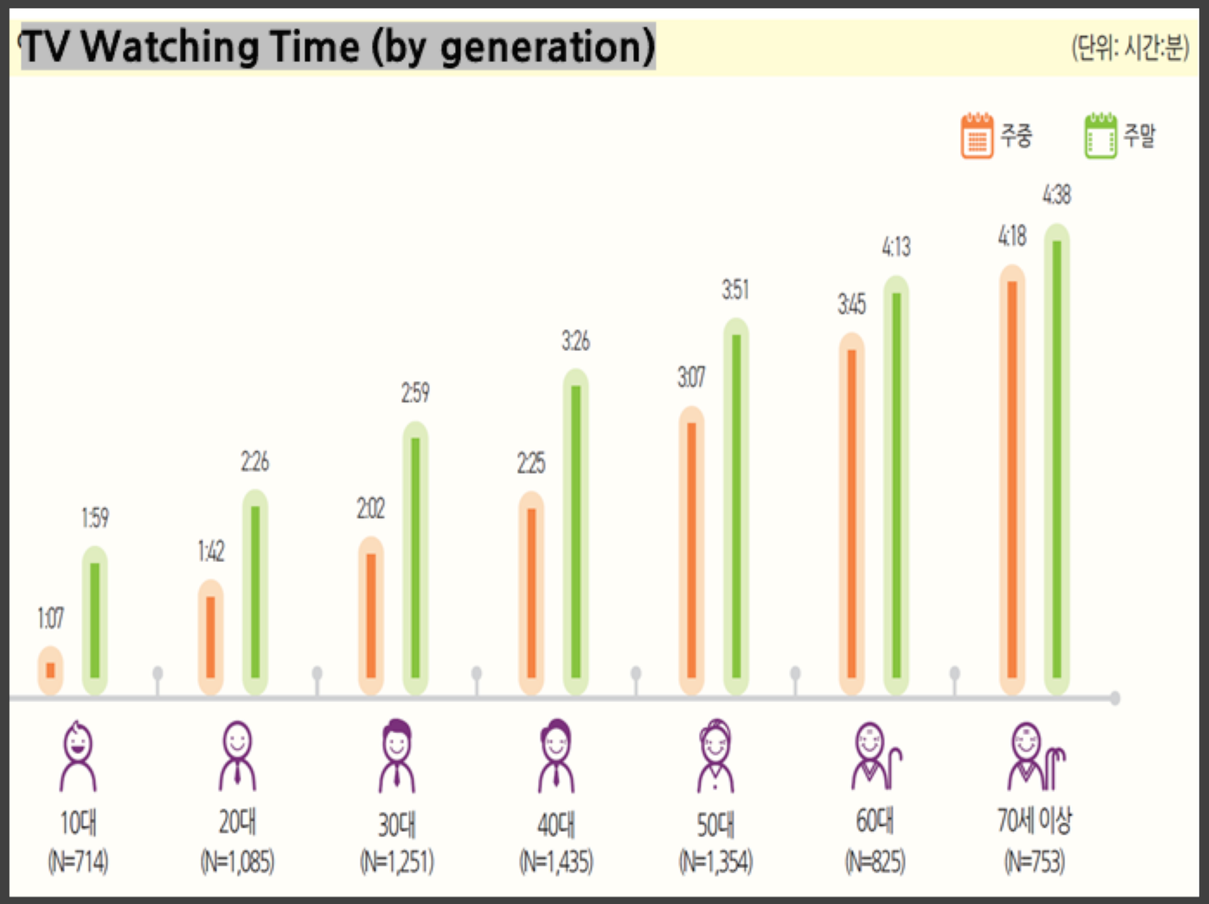
LTE-A < 50 ms → Not easy

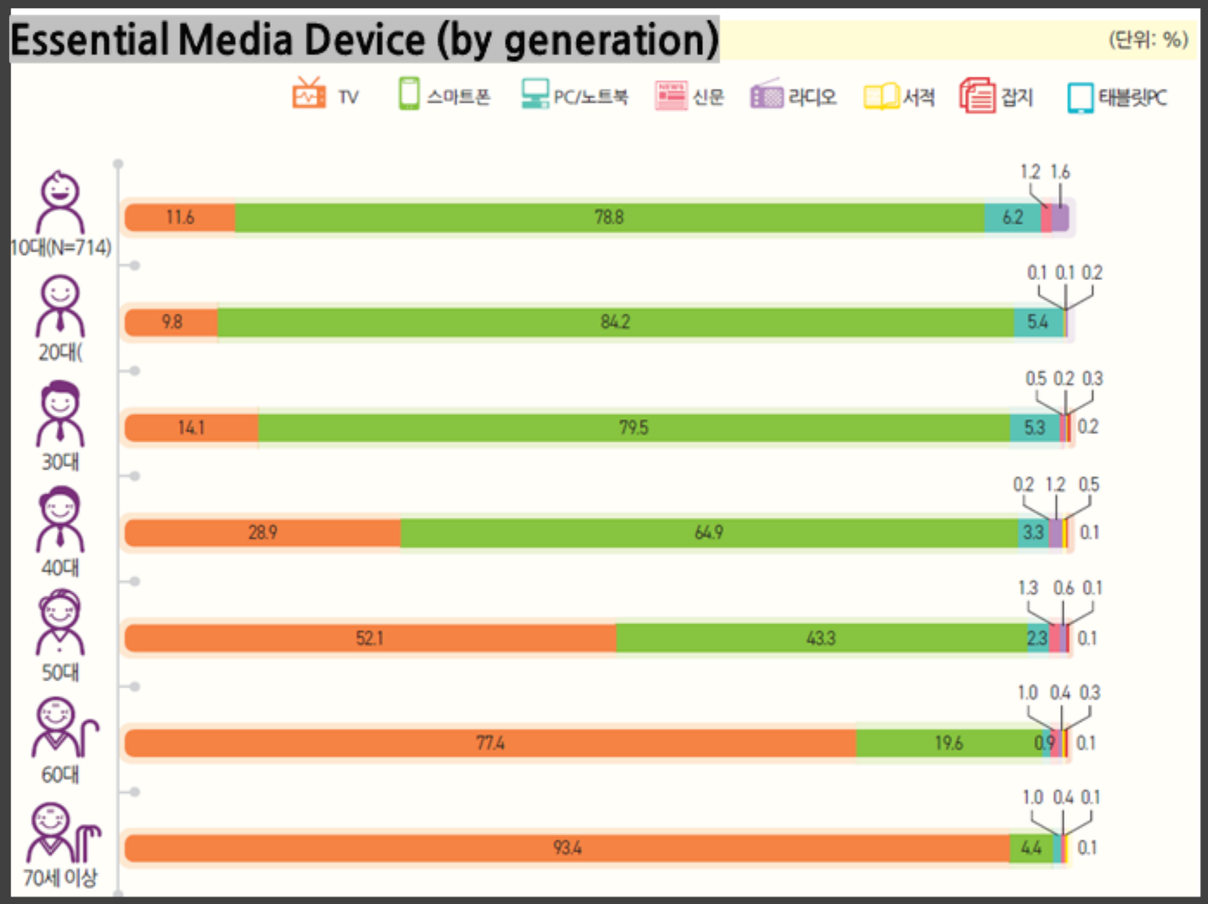
5G < 1 ms → Easy

Reference: 5G & Future Media, SK Telecom

2) Changes in Media Creation & Consumption

TV Watching Time ▼, Smartphone Usage ▲, Various Devices



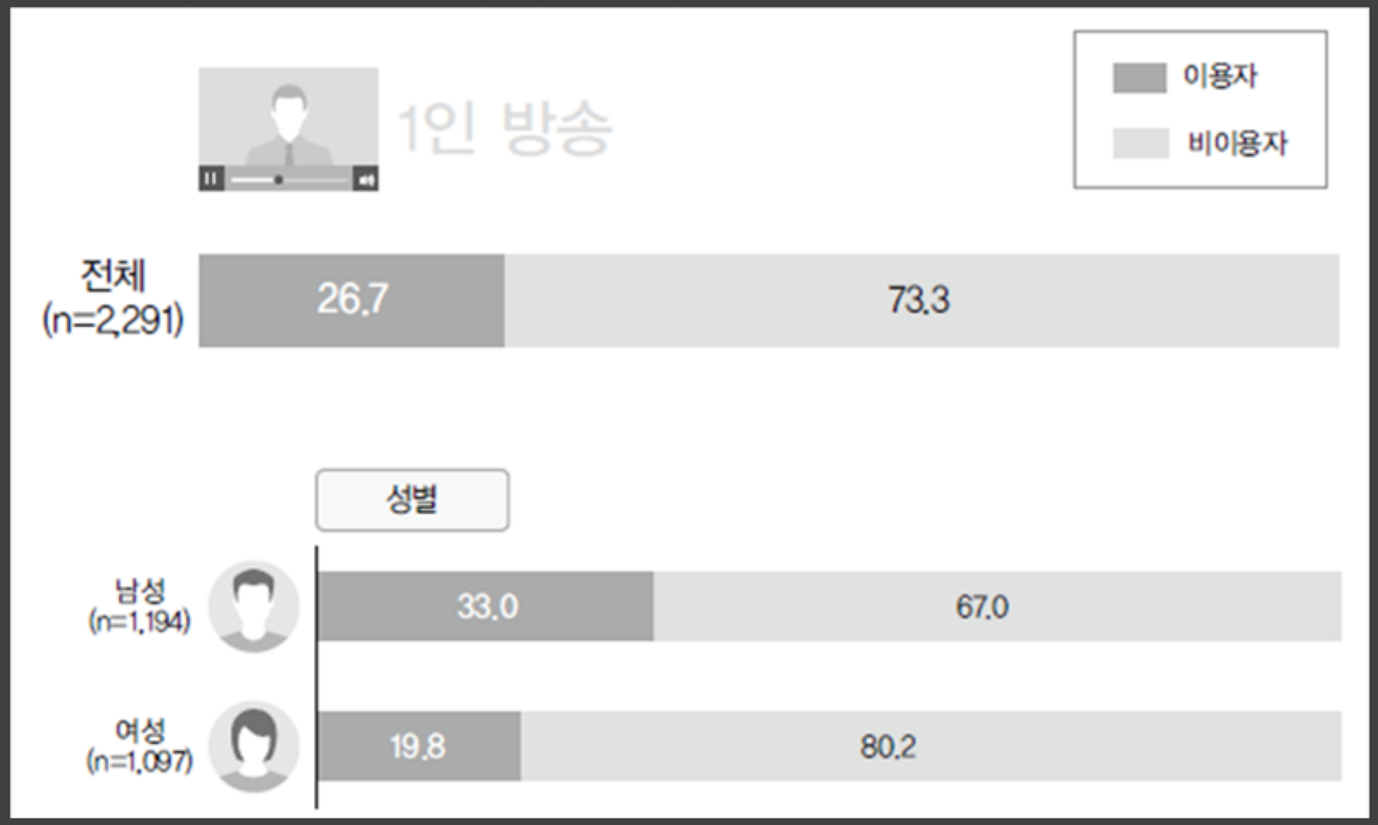


2017 Korea Media Consumption Survey, KISDI

2) Changes in Media Creation & Consumption

Spread of Personal Broadcasting

Survey result of 'Teenagers' Personal Broadcasting Usage' (2016, Korea)



afreecaTV twitch

YouTube kakaoTV

User Created Contents, On-Demand Characteristics

Along with many good contents,
violent materials and pornographies

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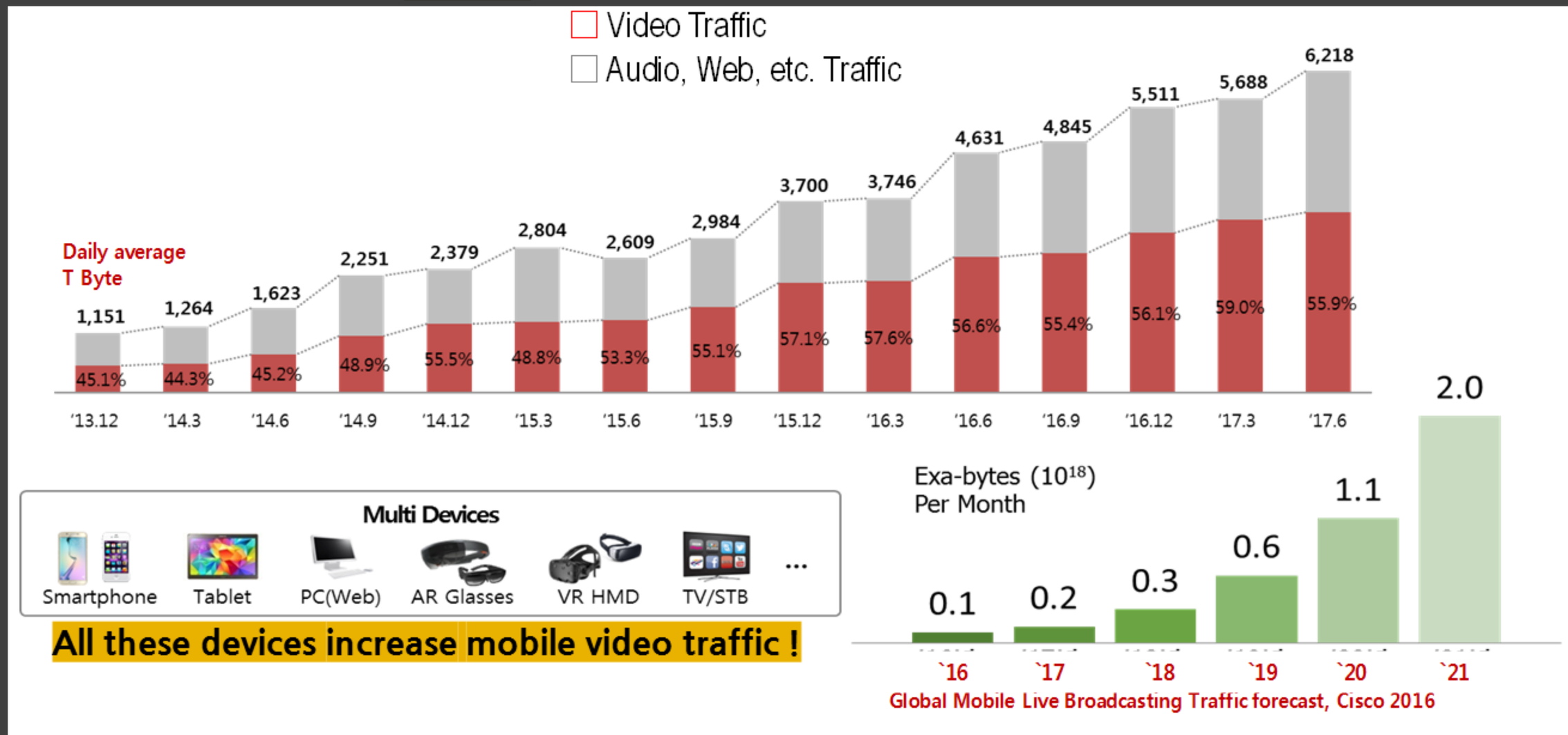
Network Speed & Capacity

Mobile video traffic is **rapidly** increasing



All these devices increase mobile video traffic !

Global Mobile Live Broadcasting Traffic forecast, Cisco 2016

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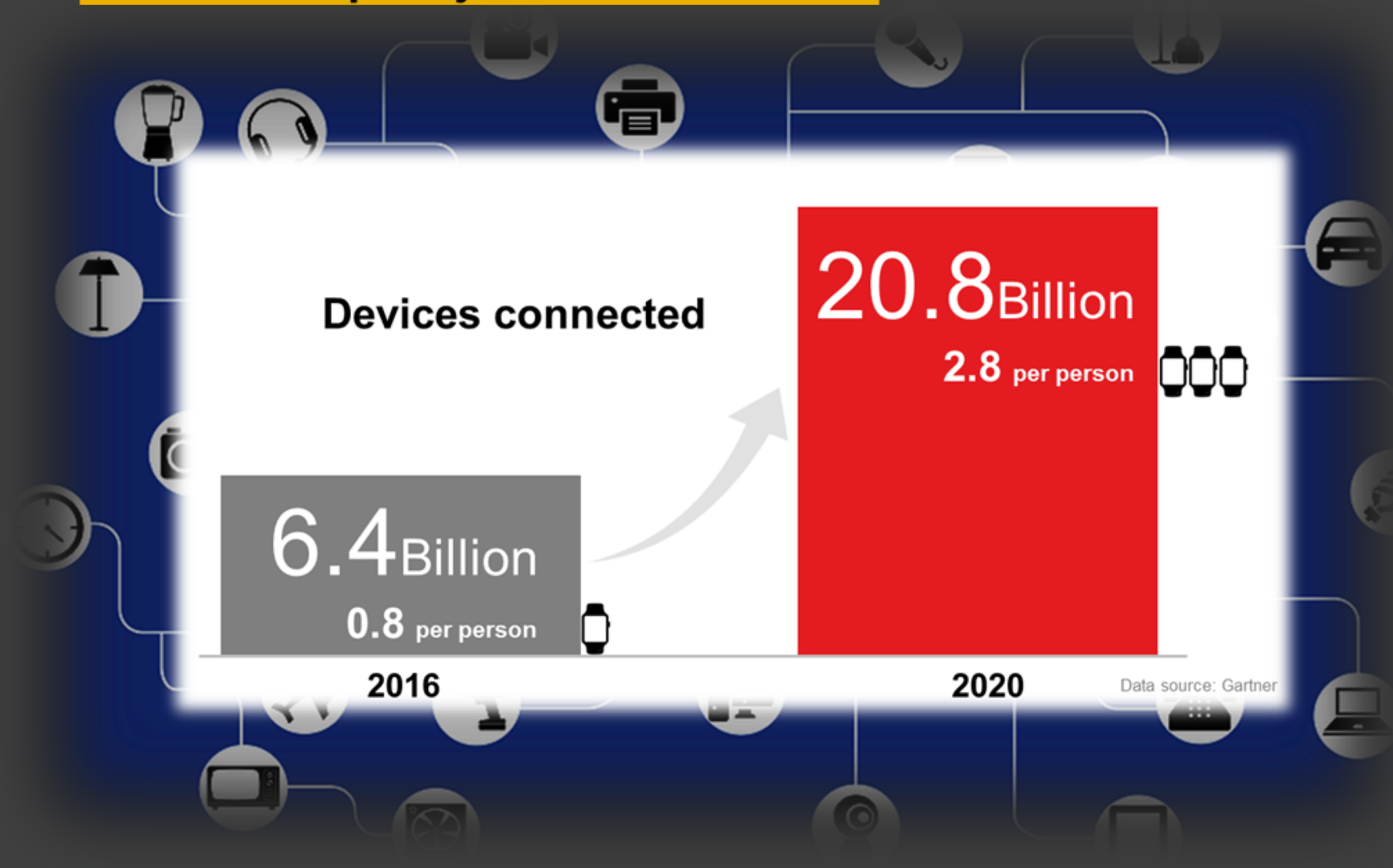
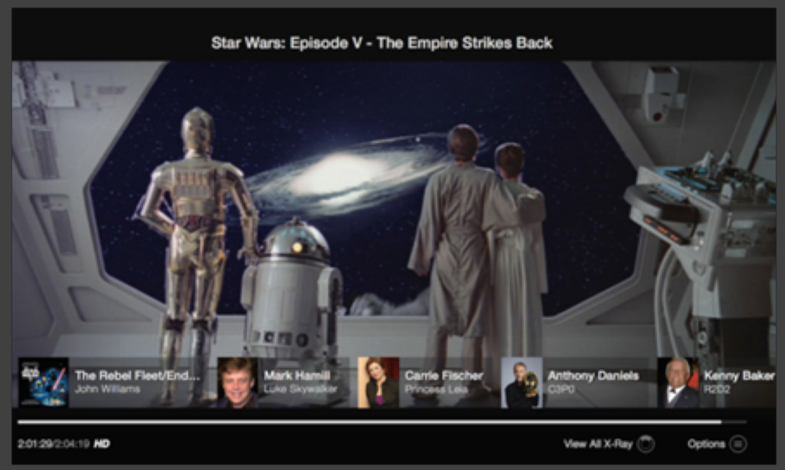
Even more devices

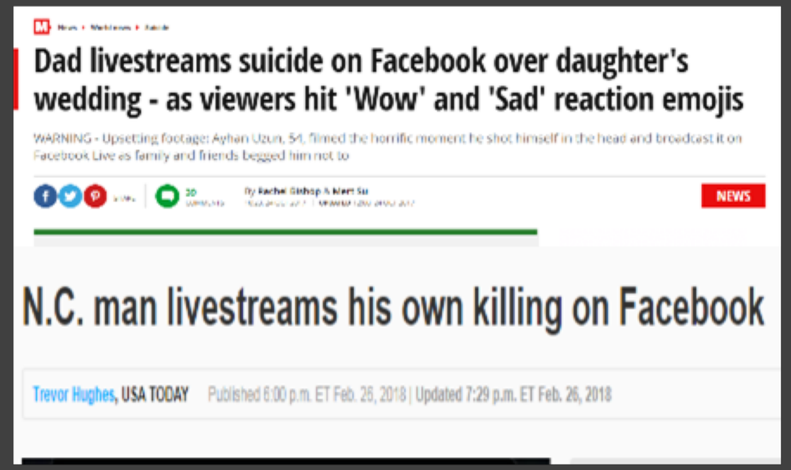
Importance of Network Capacity ▲ → 5GNetwork



Reference: 5G & Future Media, SK Telecom

3) Adoption of Artificial Intelligence





75% of Netflix Viewing Based on Personalized Recommendations

Amazon X-ray Meta-Data

AI censorship on personal broadcasting

AI Based

- Media Curation
- Meta Data Generation
- Media Censor
- Copyright/DRM
- …

Reference: 5G & Future Media, SK Telecom

Contents

- Cellular Network Overall
- IMT2020 Overall
- Automotive Applications
- Media Applications
- **5G Technology Characteristics**

Characteristics

- Massive system capacity
- High data rates everywhere
- Low latency
- Ultra-high reliability and availability
- Low device cost and energy consumption
- Energy-efficient networks
- Interoperability with existing wireless networks

Reference: https://www.ericsson.com/en/networks/trending/hot-topics/5g-radio-access

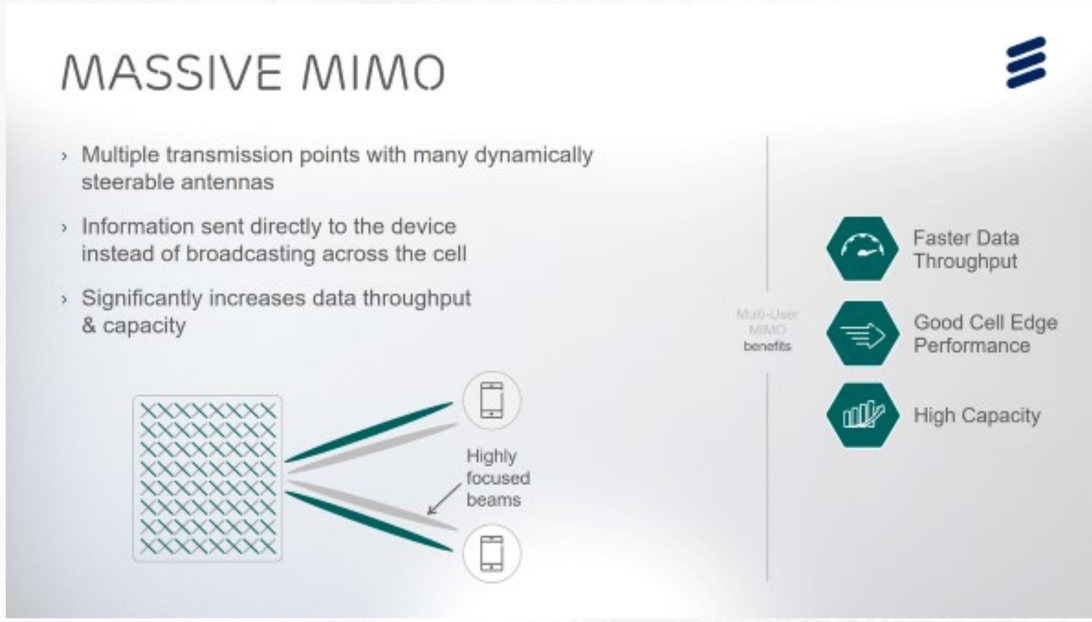
New spectrum

- To support increased traffic capacity and data throughput, 5G will extend the range of mobile communication frequencies. This includes new spectrum below 6GHz, as well as spectrum in higher frequency bands.
- Low frequency bands will continue to be the backbone of mobile networks. New high frequencies, especially those above 10GHz, will complement low frequencies as needed to provide additional system capacity or wide transmission bandwidths for extreme data rates in dense deployments.

Reference: https://www.ericsson.com/en/networks/trending/hot-topics/5g-radio-access

Massive MIMO

- Multi-antenna transmission already plays an important role in current generations of mobile communication and will be even more central in the 5G era. Massive MIMO (multiple-input and multiple-output) uses a combination of advanced antennas with a large number of steerable ports to significantly increase the number of transmission points, which increases spectral efficiency, network capacity and delivers faster data throughput.



Reference: https://www.ericsson.com/en/networks/trending/hot-topics/5g-radio-access

User centric with beamforming

- Beamforming utilizes the Massive MIMO advanced antenna array to increase the capacity and effectiveness of radio transmissions. Beamforming achieves this by shaping the radio signals into highly focused, steerable beams which deliver a stronger radio signal a greater distance and with less energy. As a result, Beamforming and Beam steering enable higher data throughput throughout the cell, and higher data rates at the cell edge. With Beamforming, the radio data transmission is sent directly to the device instead of broadcasting across the entire cell which also reduces intercell interference further improving system performance. The number and shape of the beams is controlled dynamically to meet the application needs.

Reference: https://www.ericsson.com/en/networks/trending/hot-topics/5g-radio-access

5G Radio Key Capability

Scalable and flexible air interface

Our technology inventions drove Rel-15 specifications

Scalable OFDM-based air interface

Scalable OFDM numerology

Address diverse services, spectrum, deployments

Flexible slot-based framework

Self-contained slot structure

Low latency, URLLC, forward compatibility

Advanced channel coding

Multi-Edge LDPC and CRC-Aided Polar

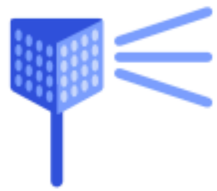
Support large data blocks, reliable control channel

Massive MIMO

Reciprocity-based MU-MIMO

Large # of antennas to increase coverage/capacity

Mobile mmWave



Beamforming and beam-tracking

For extreme capacity and throughput

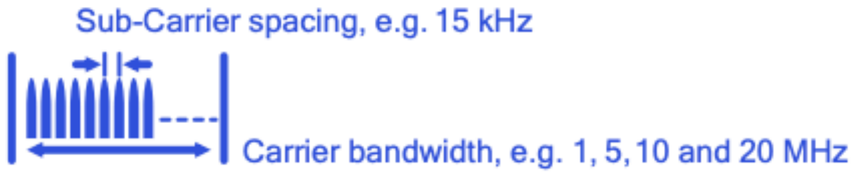
Early R&D investments | Best-in-class prototypes | Fundamental contributions to 3GPP

Reference: https://www.qualcomm.com/media/documents/files/the-3gpp-release-15-5g-nr-design.pdf

Scalable and flexible air interface

Scalable 5G NR OFDM numerology–examples

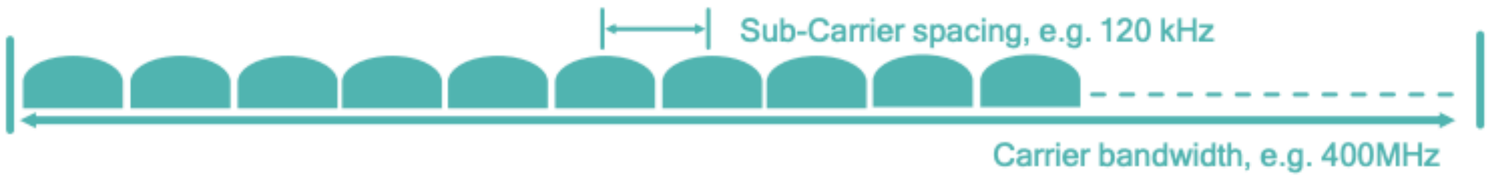
Outdoor macro coverage
e.g., FDD 700 MHz

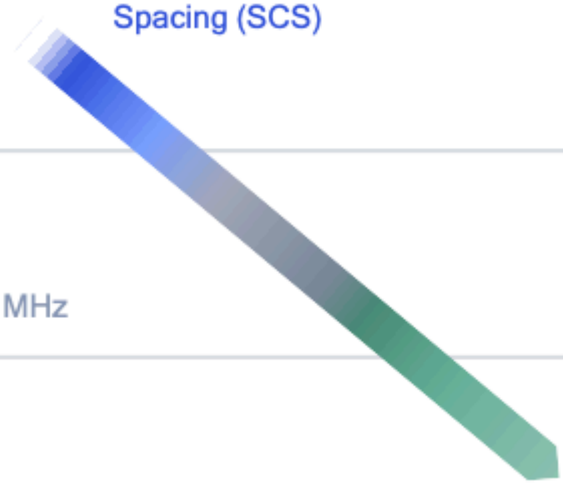


Outdoor macro and small cell
e.g., TDD 3-5 GHz

Indoor wideband
e.g., unlicensed 6 GHz

mmWave
e.g., TDD 28 GHz





Efficiently address 5G diverse spectrum, deployments and services

Scaling reduces FFT processing complexity for wider bandwidths with reusable hardware

10

Reference: https://www.qualcomm.com/media/documents/files/the-3gpp-release-15-5g-nr-design.pdf

Scalable and flexible air interface

Flexible slot-based 5G NR framework

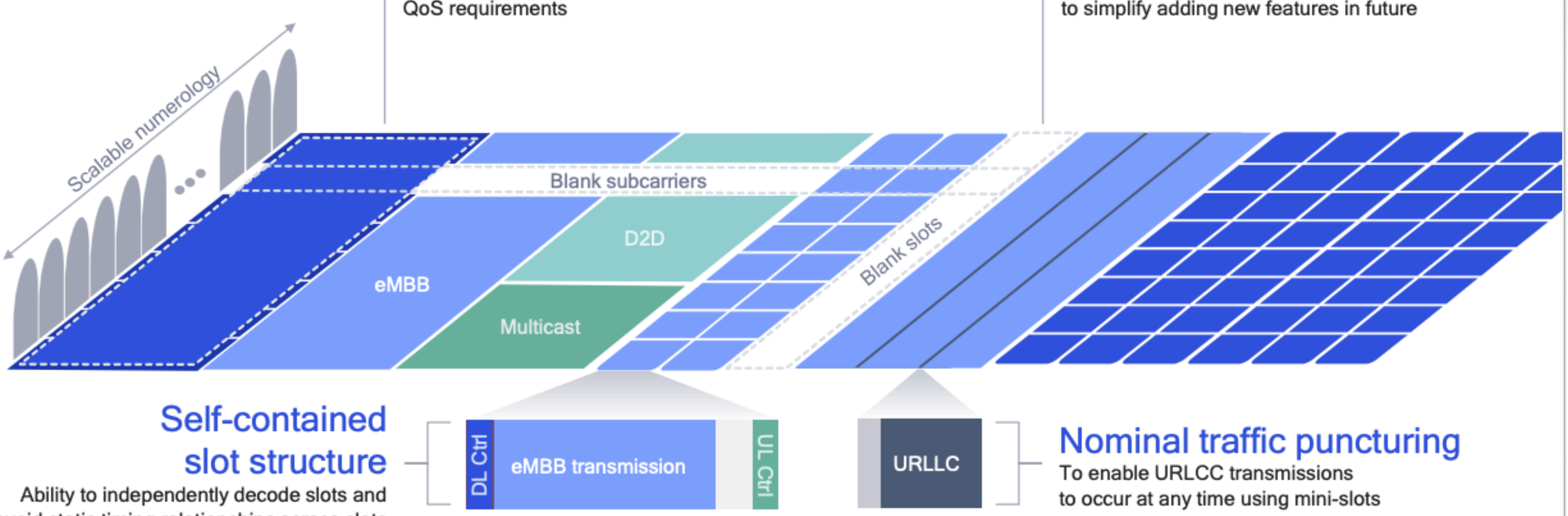
Efficiently multiplex envisioned and future 5G services on the same frequency

Scalable slot duration

Efficient multiplexing of diverse latency and QoS requirements

Forward compatibility

Transmissions well-confined in time/frequency to simplify adding new features in future



Self-contained slot structure

Ability to independently decode slots and avoid static timing relationships across slots

Nominal traffic puncturing

To enable URLCC transmissions to occur at any time using mini-slots

Reference: https://www.qualcomm.com/media/documents/files/the-3gpp-release-15-5g-nr-design.pdf

Ultra-lean design for improved energy performance

- Ultra-lean radio-access design is important to achieve high efficiency in 5G networks. The basic principle of ultra-lean design can be expressed as: minimize any transmissions not directly related to the delivery of user data. Such transmissions include signals for synchronization, network acquisition and channel estimation, as well as the broadcast of different types of system and control information.
- Ultra-lean design is especially important for dense deployments with a large number of network nodes and highly variable traffic conditions. However, lean transmission is beneficial for all kinds of deployments, including macro deployments.

Reference: https://www.ericsson.com/en/networks/trending/hot-topics/5g-radio-access

Network evolution

- Networks are evolving to meet the needs of new use cases with different demands on mobility, data rates, latency, reliability and device density.

Reference: https://www.ericsson.com/en/networks/trending/hot-topics/5g-radio-access

Virtualized RAN for 5G

- Some of the RAN functions that are less sensitive to time delay which are hosted within the baseband units have the opportunity to become virtualized to increase network flexibility.
- For example, the multipath-handling function that is the anchor point for dual connectivity in 5G can be further optimized. By moving this function higher up in the network, “tromboning” traffic delays and inefficiencies can be avoided.

Reference: https://www.ericsson.com/en/networks/trending/hot-topics/5g-radio-access

Fronthaul for 5G: eCPRI

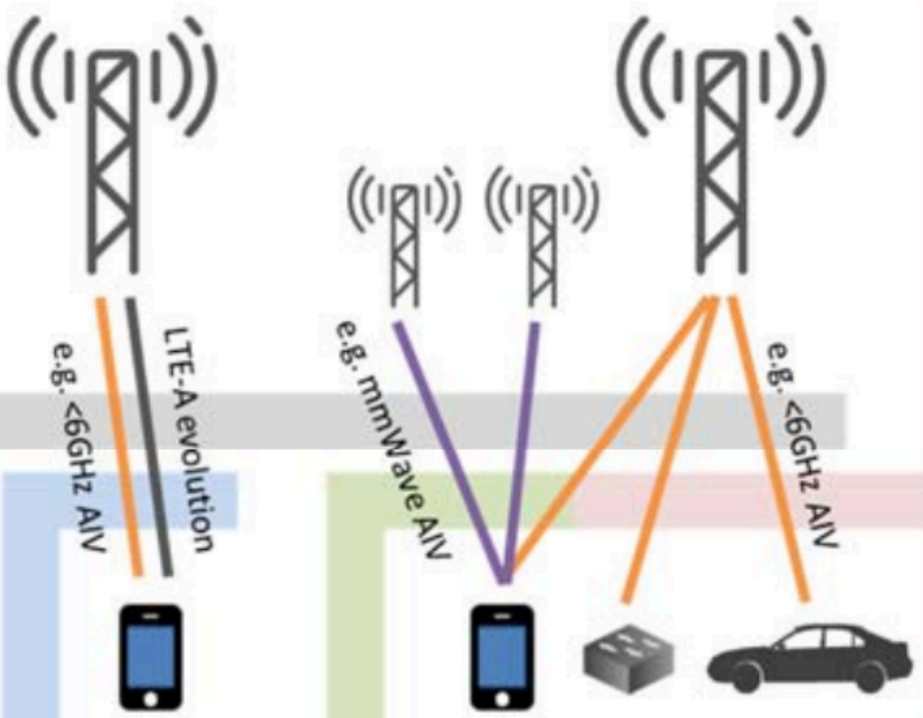
- To meet the needs for 5G, the new industry standard 5G fronthaul—eCPRI—will improve bandwidth efficiency, increase capacities and lower latencies.
- Ericsson has implemented the market's first commercial eCPRI interface in Ericsson Radio System. Its bandwidth scales flexibly with user traffic and allows for a 10x reduction of bandwidth on the interface. eCPRI will use standard Ethernet connections over dedicated fiber.
- By using the eCPRI interface, Ericsson has moved beamforming processing from the baseband to the radio. This allows for a much simpler Massive MIMO deployment and provides the flexibility needed in real-life site environments.

Reference: https://www.ericsson.com/en/networks/trending/hot-topics/5g-radio-access

5G Air Interface Envisioned

Harmonization

- Between LTE-A evo. and novel 5G AIVs, harmonization benefits have to be weighed against legacy constraints imposed towards novel AIVs
- Among novel 5G AIVs, maximum harmonization should be aimed for, but it is not sure whether full harmonization for all bands and services is possible

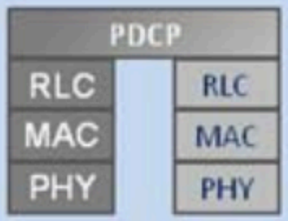


Service Multiplexing

- All novel protocol stack layers and related functions introduced in 5G should natively support service multiplexing for xMBB, mMTC, uMTC*

* Though some bands and related AIVs may be predestined for a subset of services (e.g. mmWave mainly for xMBB)

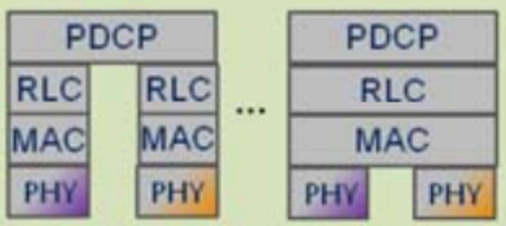
Integration among LTE-A evolution and novel 5G AIVs



- RAN level integration should be supported
- PDCP is seen as a viable UP aggregation layer, though also MAC layer is investigated

- Cases with single and dual RRC protocol instances above PDCP investigated (e.g. one for LTE-A evo. one for novel 5G AIV)
- LTE RRC instance may also relay 5G RRC information in a transparent manner

Integration among novel 5G AIVs



(for instance considering aggregation between mmWave and <6GHz AIV)

- User plane aggregation could take place on PDCP, RLC or MAC level

- Single RRC protocol instance envisioned above PDCP
- Different forms of signaling, such as RRC or control plane diversity or fast control plane switching are considered

PHY: Physical layer, MAC: Medium access control, RLC: Radio link control, PDCP: Packet data convergence protocol

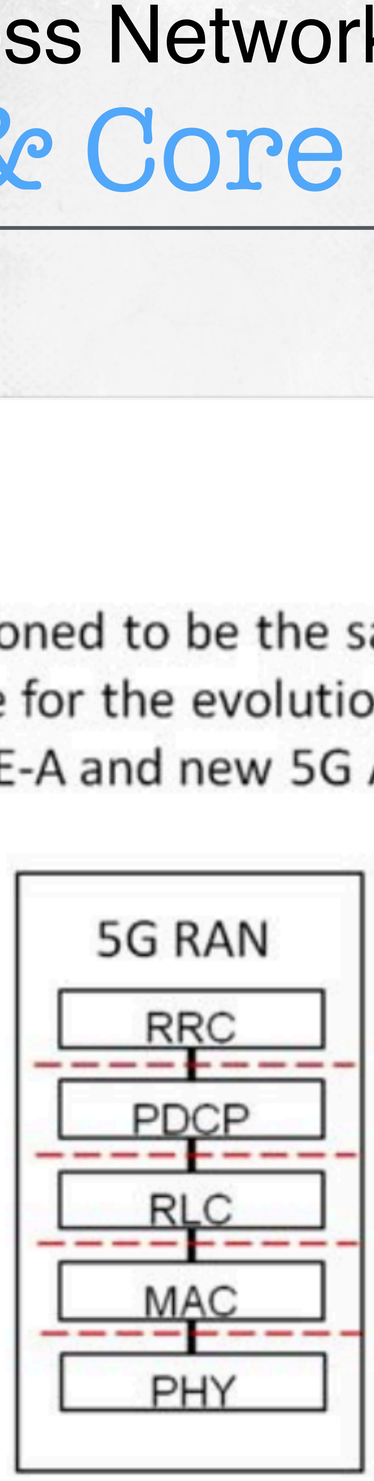
Reference: https://www.ericsson.com/assets/local/publications/conference-papers/5g_radio_access_network_architecture.pdf

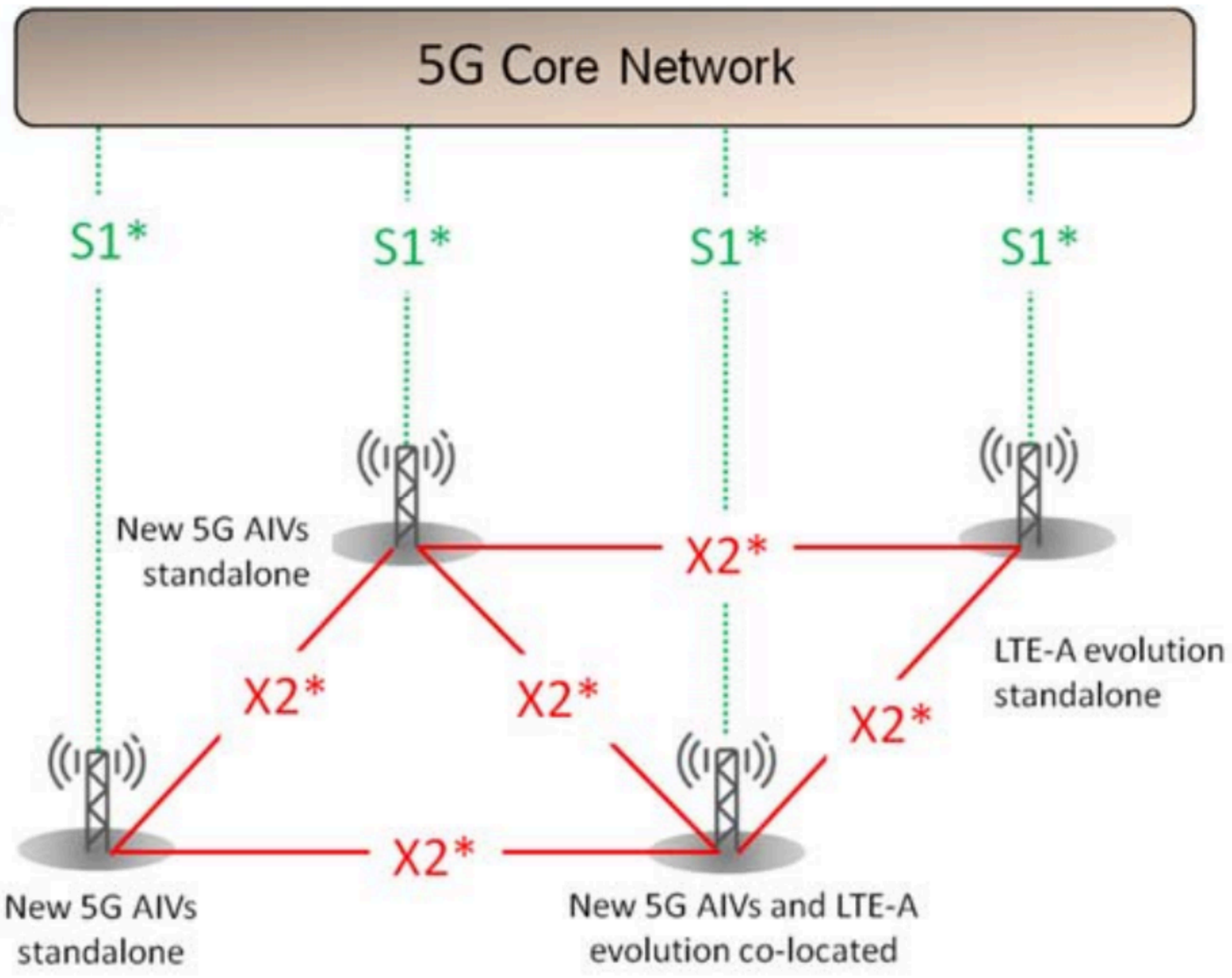
5G RAN & Core Overall

S1* is envisioned to be the same CN/RAN interface for the evolution of LTE-A and new 5G AIVs

Avoid strict time constraints among protocol functions to enable multiple functional Splits.

Further splits within the layers shall not be excluded.



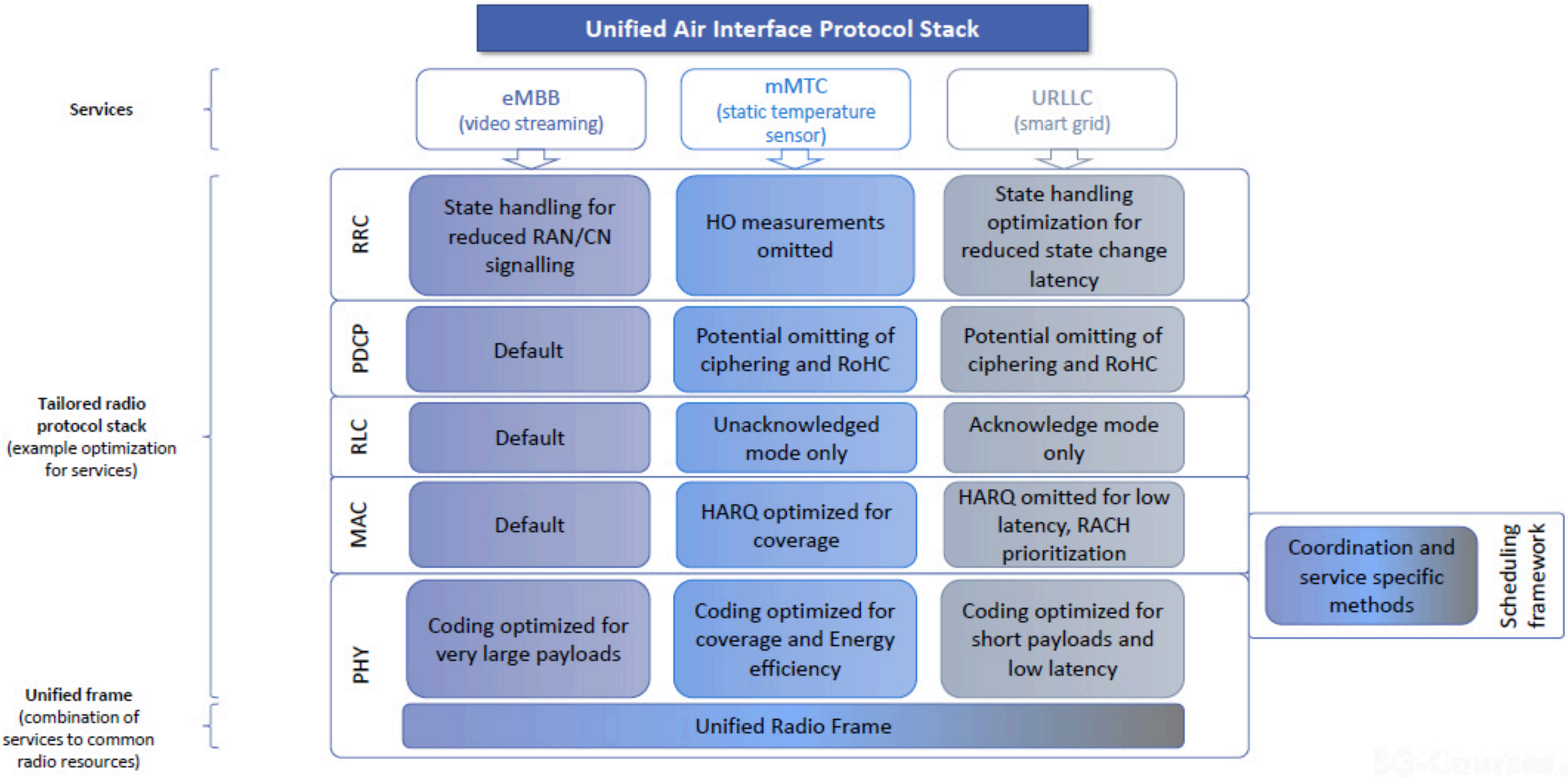


Reference: https://www.ericsson.com/assets/local/publications/conference-papers/5g_radio_access_network_architecture.pdf

5G MAC/DLC tailoring

5G Air Interface

Unified Air Interface (UAI) and Scalable PHY Construction

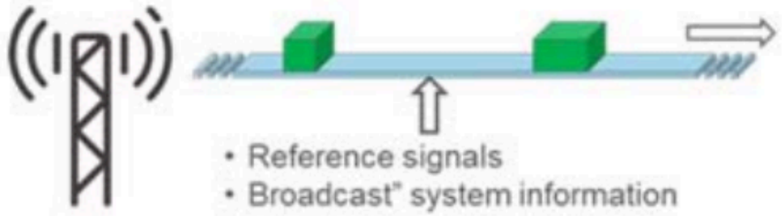


Reference: https://telecom-knowledge.blogspot.com/2017/03/5g-air-interface.html

Beam-centric, lean & future-future-proof signaling

a)

"Always on" reference signals and system information



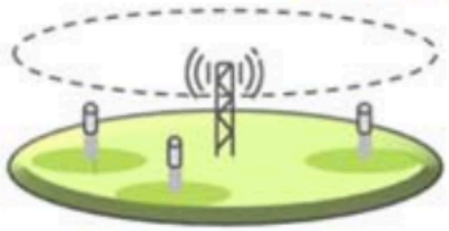
- Reference signals
- Broadcast" system information
- ...

More dedicated transmissions

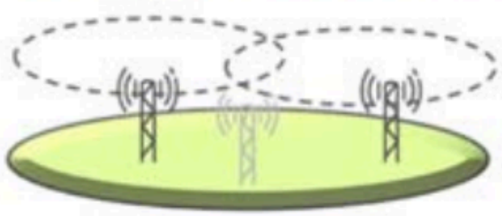
- No "always-on" refeference signals
- Minimum amount of "always-broadcast "system information
- ...

Novel schemes to distribute system information

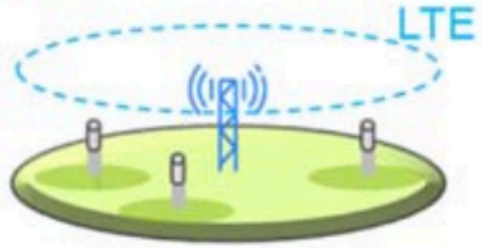
b)



Delivered by overlaid node



Jointly delivered by MBSFN

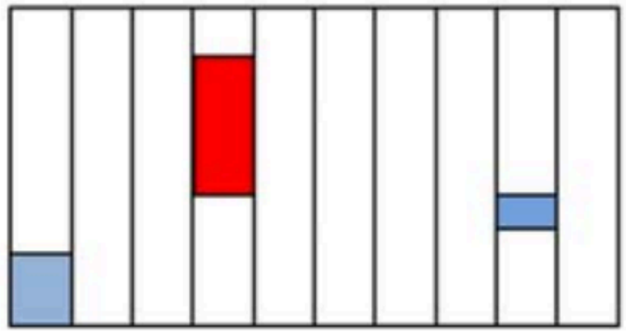


Delivered by LTE

c)

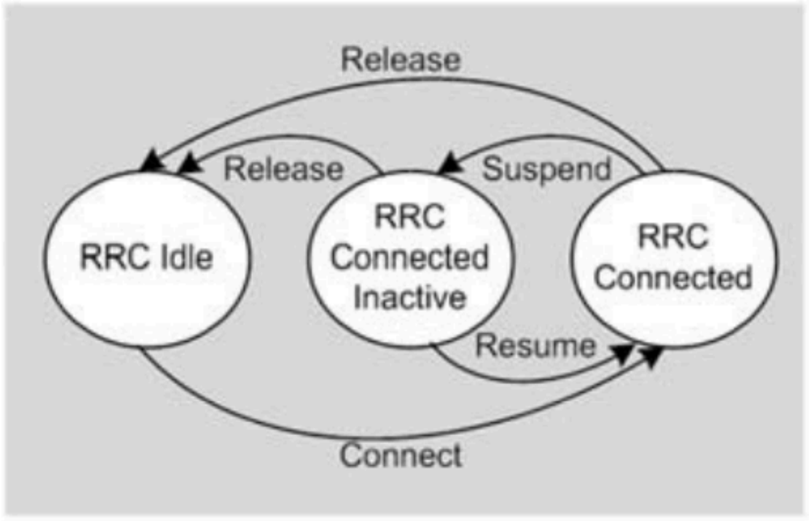
Reference signals and control channels all over the band

Self-contained transmissions



Reference: https://www.ericsson.com/assets/local/publications/conference-papers/5g_radio_access_network_architecture.pdf

Air Interface Signaling Enhancement



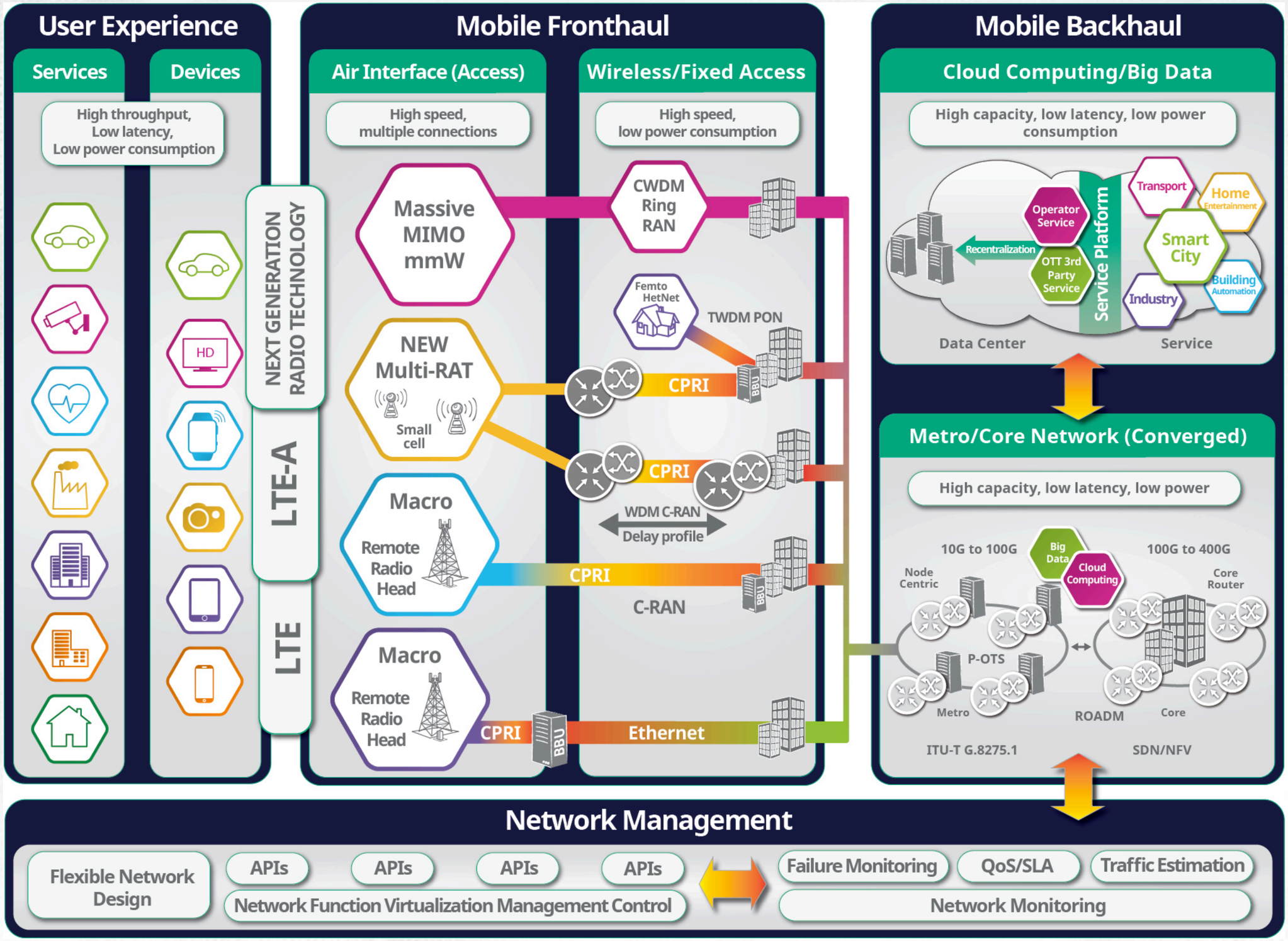
	4G	5G	Gain
	(Transition from idle to connected)	(Transition from connected inactive to connected)	
Signaling overhead	13x RRC messages* 8x S1AP messages** *7 if the CN has kept some context information **3 if the CN has kept some context information	2x RRC messages Network signaling related to context fetching* * Though this may be negligible if UE returns to same area	At least 70% signaling reduction
Control Plane Latency	RA delay + 3.5x radio RTT + S1 RTT	RA delay + radio RTT	Reduction by 2x radio RTT + S1 RTT

S1AP: S1 Application Protocol, RTT: Round trip time

Reference: https://www.ericsson.com/assets/local/publications/conference-papers/5g_radio_access_network_architecture.pdf

5G Networking

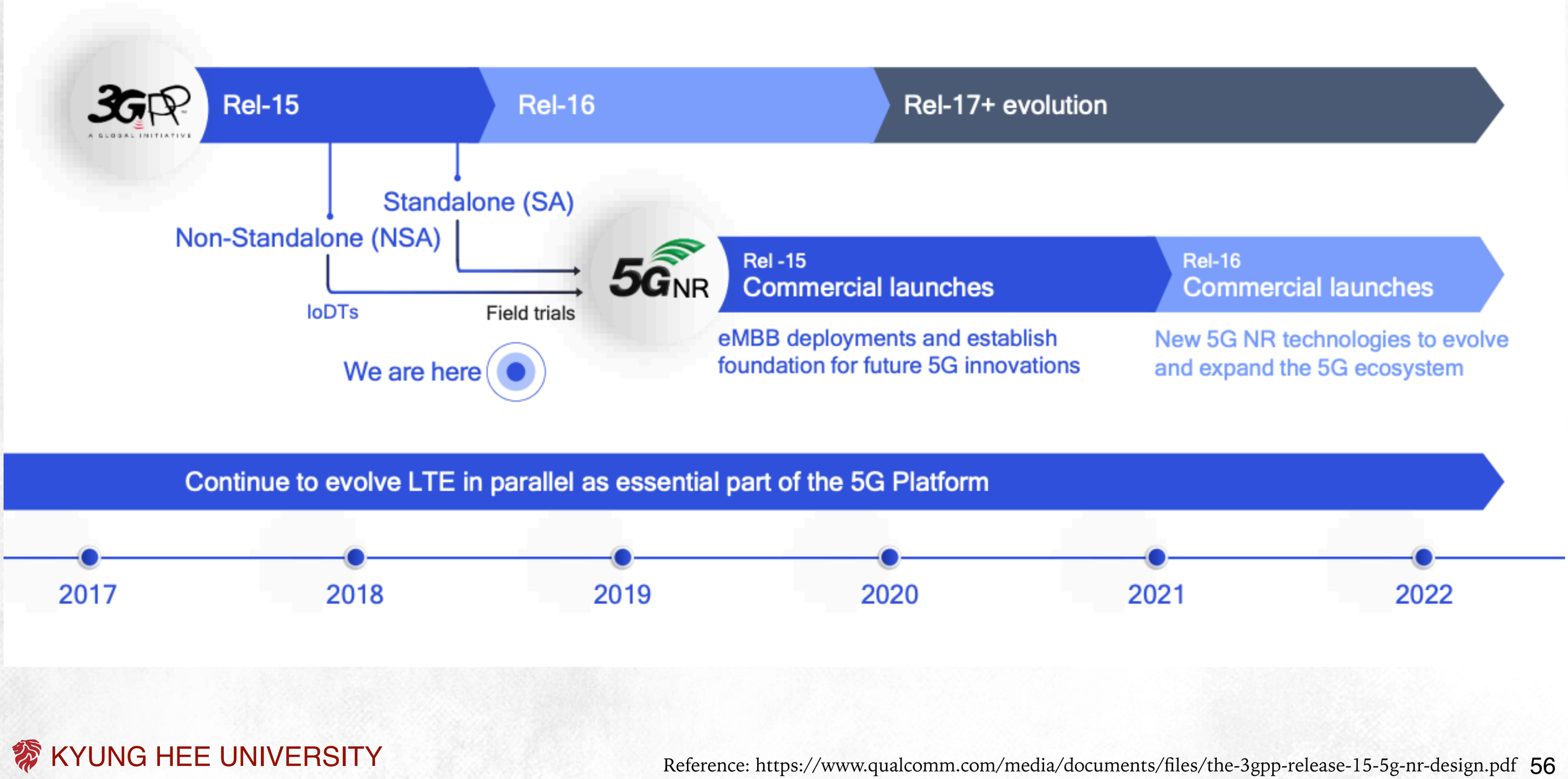
Birds-Eye-View



Reference: https://www.anritsu.com/en-US/test-measurement/technologies/5g-everything-connected/5g-everything-connected-detail

Birds-Eye-View

Driving the 5G roadmap and ecosystem expansion



Reference: https://www.qualcomm.com/media/documents/files/the-3gpp-release-15-5g-nr-design.pdf

Thank you

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