

# 5G Networks and Beyond

(Day 1. 5G 네트워크 개요)



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- **Day 1: 5G 네트워크 개요**
- **Day 2: Enhanced Mobile Broadband**
- **Day 3: Private 5G와 테스트베드**
- **Day 4: 5G 네트워크 인프라 가상화 기술**
- **Day 5: Cloud Native 5G 인프라**
- **(별도) Day 4~5 실습교재**

## ➤ Day 1: 5G 네트워크 개요

- 5G 네트워크 개요
- 5G 네트워크 표준과 기술 발전 (5G/6G)
- 5G 네트워크 인프라 (하드웨어/가상/클라우드)
- 5G 네트워크의 Use Case

# DAY 1: 5G 네트워크 개요

## ❖ 5G 서비스 시장 (Forecast 2022 – 2030)

- ✓ **통신 방식:** FWA, eMBB, uRLLC, mMTC
- ✓ **수직 시장:** Manufacturing, Public Safety, Healthcare & Social Work, Media & Entertainment, Energy & Utility, IT & Telecom
- ✓ **사용자:** Consumers, Enterprises

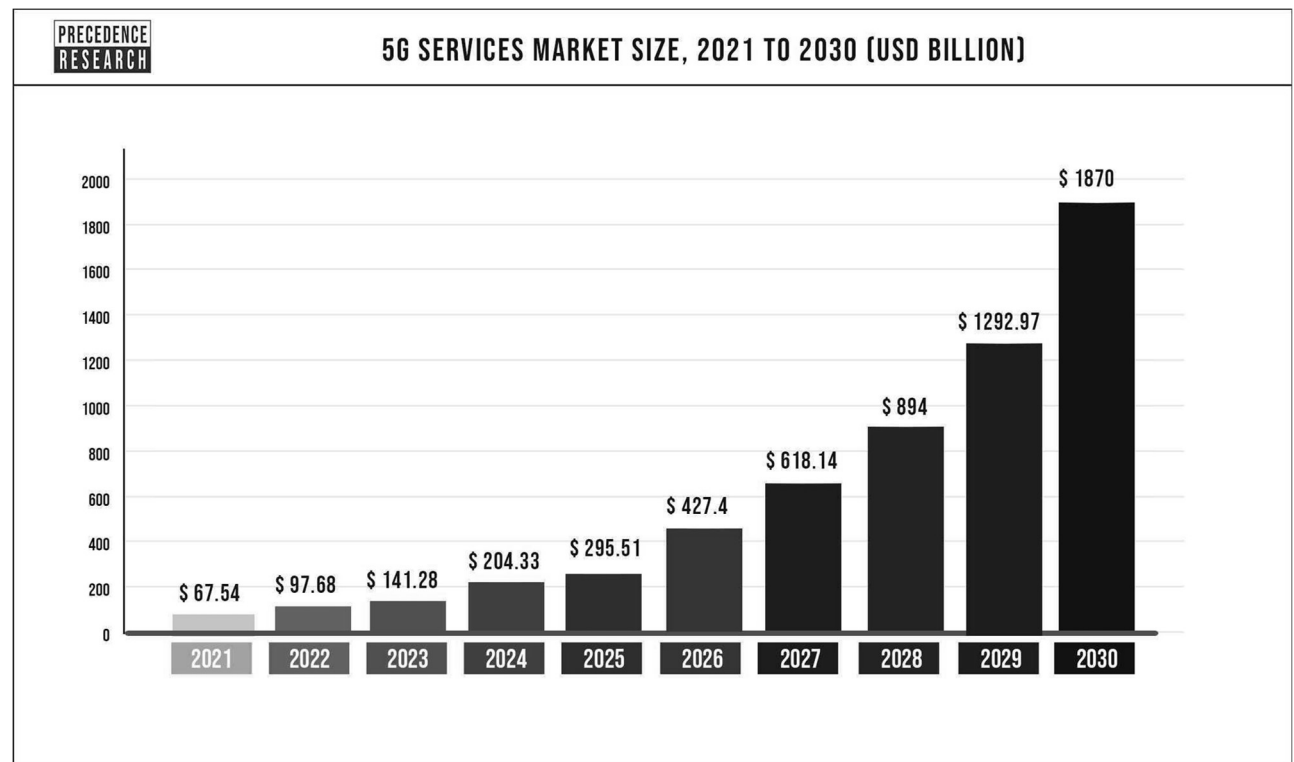
**FWA** (Fixed Wireless Access)

**eMBB** (enhanced Mobile Broadband) 대역폭 개선

**uRLLC** (Ultra Reliable Low Latency Communications) 초저지연

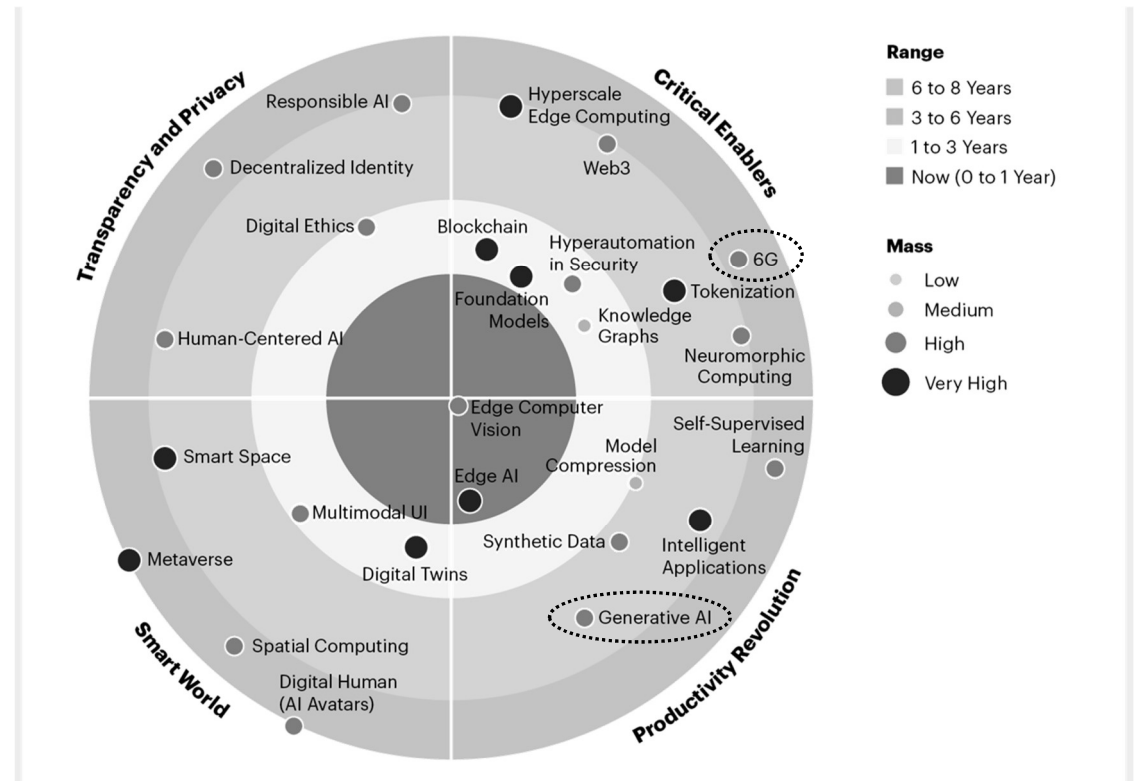
**mMTC** (massive Machine Type Communications) 대량 접속

Source: <https://www.precedenceresearch.com/5g-services-market>



# DAY 1: 5G 네트워크 개요

## ❖ 2023 Gartner Emerging Technologies and Trends Impact Radar



Source: [https://www.linkedin.com/posts/software-group-bg-ltd\\_4-emerging-technologies-you-need-to-know-activity-7028965654405820416-8XBQ](https://www.linkedin.com/posts/software-group-bg-ltd_4-emerging-technologies-you-need-to-know-activity-7028965654405820416-8XBQ)



# DAY 1: 5G 네트워크 개요

## ❖ Use Cases



연결성은 도로에서의 사고 감소와 연비 향상으로 이어질 수 있다.

© Bosch



5G의 속도는 수술용 AR과 같은 프로그램을 사용할 때 지연 시간을 줄일 수 있다.

© Verizon



오culus 퀘스트는 최초의 올인원 VR 게임 시스템 - 선이 필요 없음

© Oculus



# DAY 1: 5G 네트워크 개요

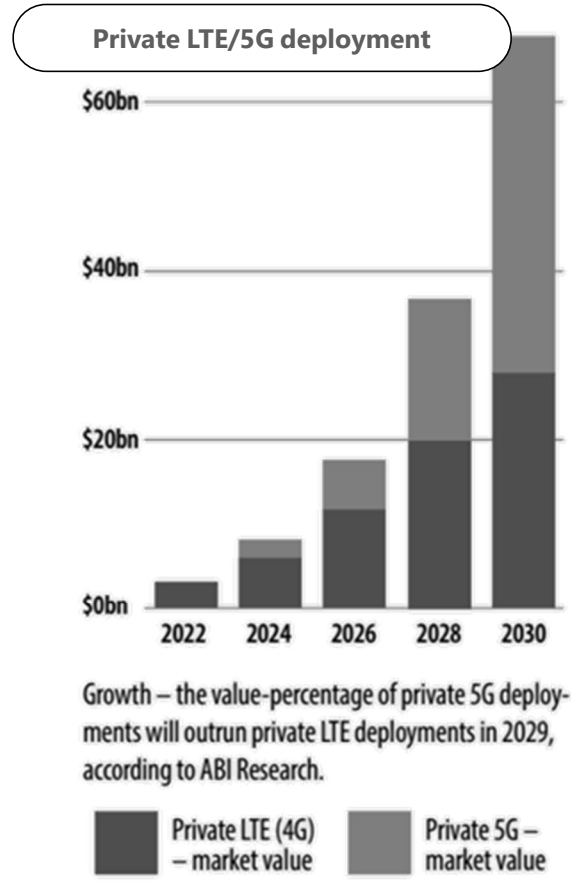
- ❖ Private 5G
- ❖ Private LTE/5G

	INDUSTRY	SITES	SIZE
스마트팩토리	Industrial & manufacturing	10,710,000	IM+
창고	Warehouses	3,300,000	
병원/연구소	Hospitals & labs	263,000	100K+
	Water utilities	140,000	
	Mining	54,000	10K+
	Transport venues & ports	50,000	
	Power generation	47,600	
	Military bases	10,000	
	Oil & gas	8,000	1K+
	<b>TOTAL</b>	<b>14,582,600</b>	

Potential venues for private 5G

Source: Nokia

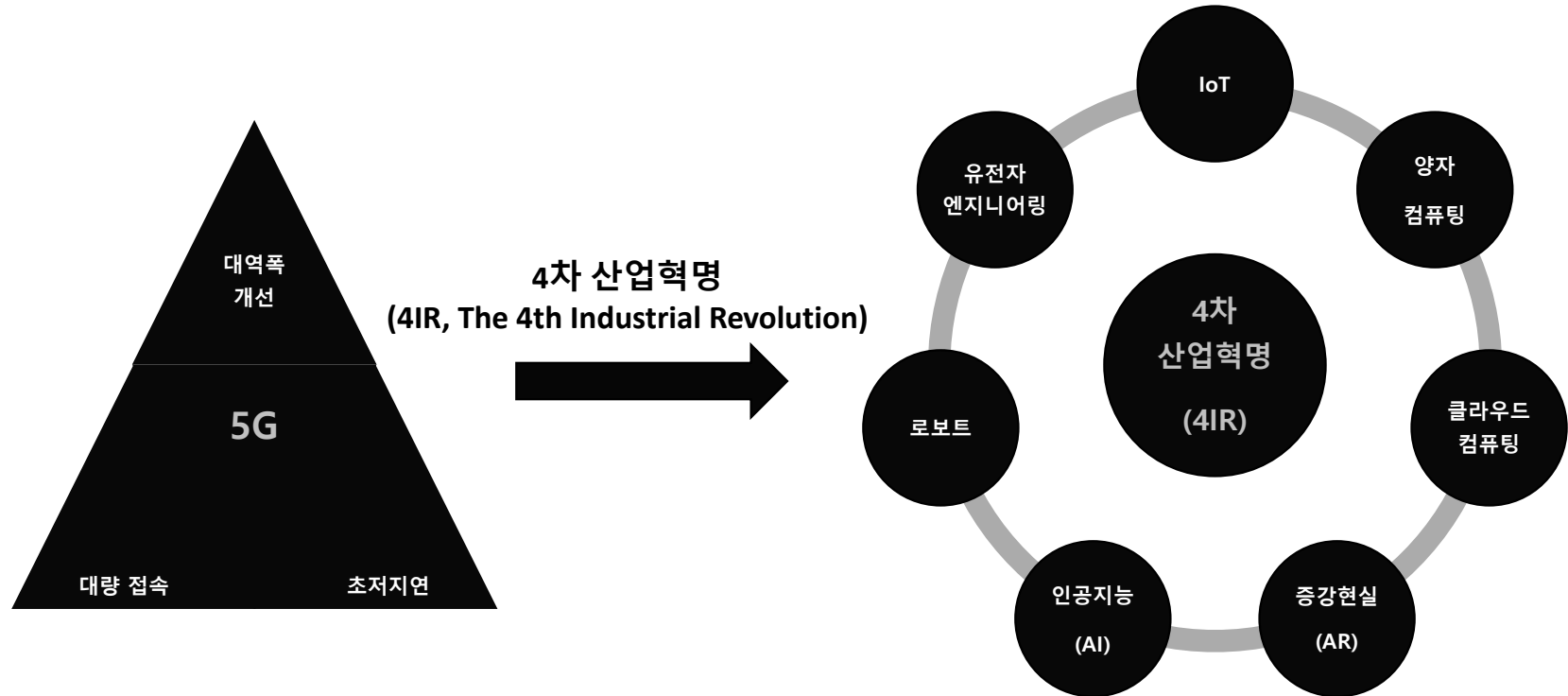
Source: 노키아



# DAY 1: 5G 네트워크 개요

## ❖ 5G Enablers 4IR

- Steam (1차 산업혁명) → Assembly Line (1차 산업혁명) → Digital (3차 산업혁명) --> 4IR





# DAY 1: 5G 네트워크 개요

## ❖ 5G SA, IoT, ecosystem and popular use cases

### 5G SA Ecosystem

#### 5G Standalone System

- eMBB
- URLLC
- MIoT
- HMTC
- V2X

#### 5G RAN

- Higher bandwidth – UL/DL
- Lower cost per bit
- Lower Latency
- Faster handovers
- Quicker connect times

#### 5G Core SBA and MEC

- Cloud Native Technology
- Network Slicing
- MEC

#### 5G Servers

- High-performance Compute (CPUs, GPUs, NPUs, VPUs)
- UPF performance optimized for high data throughput, low latency, and low jitter
- Energy efficient

#### AI/ML Data Analytics

- Descriptive Analytics
- Diagnostic Analytics
- Real-Time Analytics
- Predictive Analytics
- Prescriptive Analytics
- Cognitive Analytics

### Internet of Things (IoT)

#### IoT Sensors

- Acceleration
- Gyroscopic
- Locations Tracking
- Image
- Infrared
- Motion
- Optical
- Position
- Proximity

#### IoT Actuators

- Electrical
- Hydraulic
- Magnetic
- Mechanical
- Pneumatic
- Relay
- Thermal

#### IoT Devices

- High-Resolution Cameras
- AR Glasses
- Autonomous Vehicles
  - Automated Guided Vehicles (AGVs)
  - Autonomous Mobile Robots (AMRs)
  - Drones
  - Off-road vehicles
  - On-highway vehicles

### Popular Mfg. Use Cases

#### Quality Inspection, Surveillance, and Security

- Sensors
- Cameras
- AMRs
- Drones

#### Predictive Maintenance

- Sensors
- Cameras

#### Troubleshooting Guidance

- AR Glasses

#### Operator Training

- AR Glasses
- AMRs

#### Material/Inventory Handling

- Sensors
- Cameras
- AGVs
- AMRs
- Off-road Trucks

#### Remote Equipment Operation

- Sensors
- Actuators
- Cameras

#### Computer Vision Capabilities

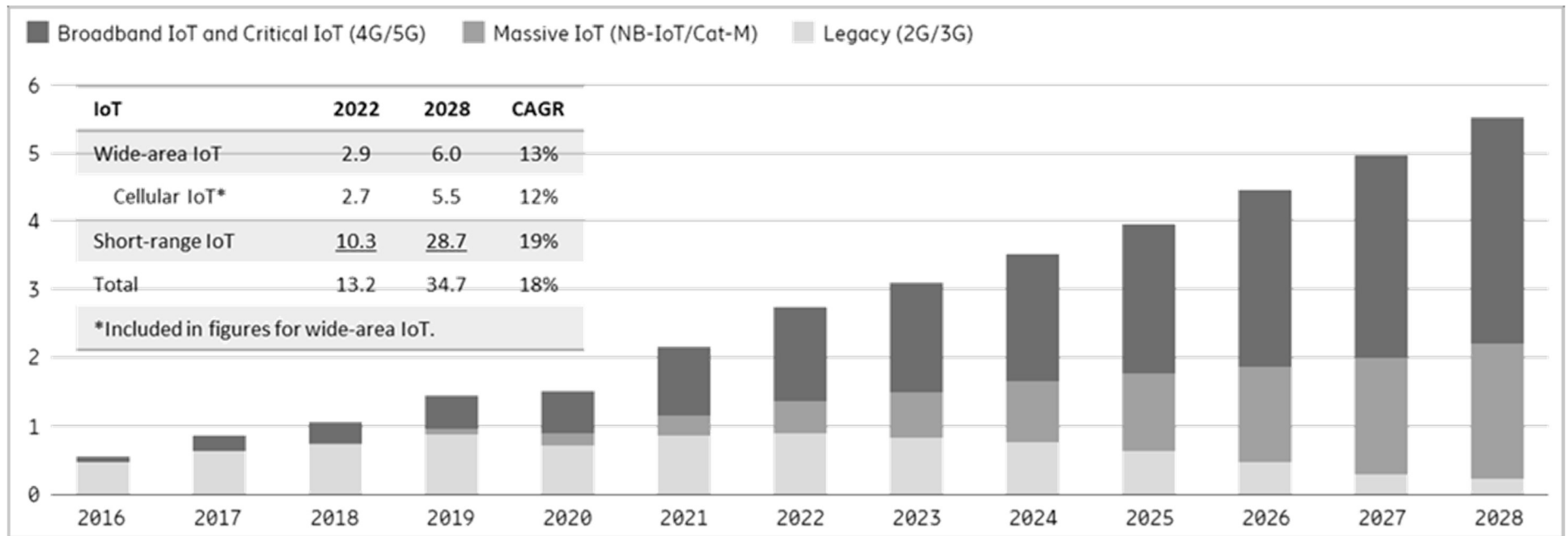
- Image Recognition
- Object Recognition
- OCR
- Facial Recognition
- Iris Recognition
- Retinal Recognition
- Gesture Recognition
- Event Recognition

Source: Dell'Oro Group



# DAY 1: 5G 네트워크 개요

❖ Cellular IoT connections (billion) – 60% of 5.5 billion to be Broadband IoT by 2028



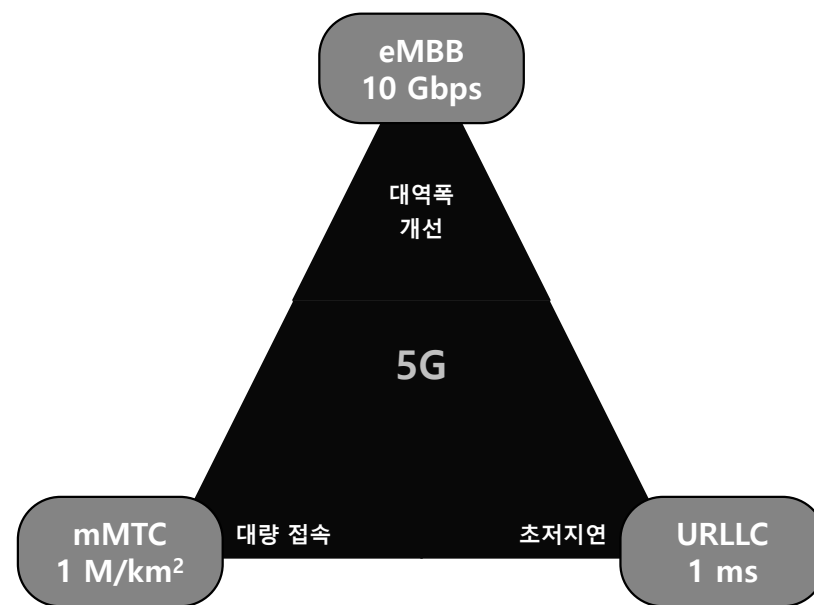
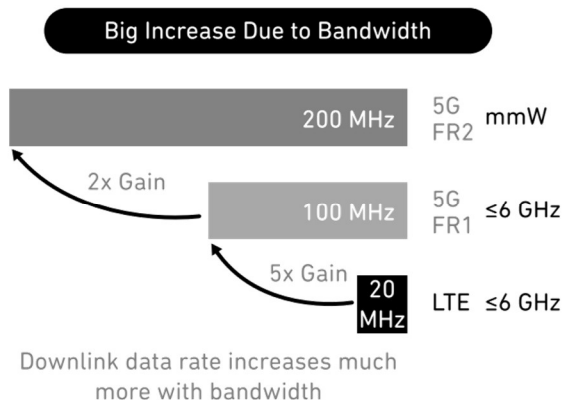
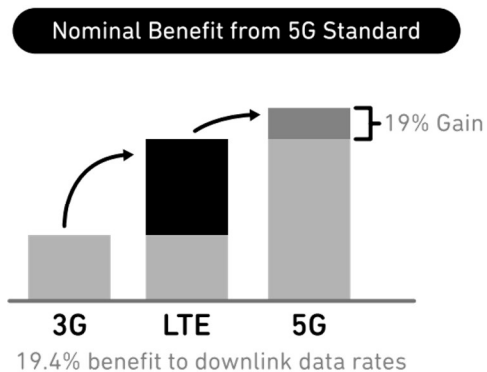
Source: Ericsson Mobility Report, November 2022



# DAY 1: 5G 네트워크 개요

## ❖ 5G의 장점

- eMBB
- URLLC
- mMTC



eMBB (enhanced Mobile Broadband); URLLC (Ultra Reliable Low Latency Communications); mMTC (massive Machine Type Communications)  
 Source: 5G RF, 2nd Qorvo Special Edition, by David Schnauffer, Tuan Nguyen, Ben Thomas, Alexis Mariani, Paul Cooper, Bror Peterson, Phil Warder



# DAY 1: 5G 네트워크 개요

## ❖ 5G 무선 표준 기관

- 이동통신 기술의 진화와 세대별 특징 / 명칭

마케팅 용어	ITU 용어	3GPP 용어	RAN 용어	Core 용어	시스템 이름
3G	IMP-2000	UMTS	UTRAN	UMTS Core	UMTS System
3.5G	Enhanced IMT-2000	UMTS HSPA	UTRAN	UMTS Core	UMTS System
4G	IMT-Advanced	LTE-Advanced	E-UTRAN	EPC (Evolved Packet Core)	EPS (Evolved Packet System)
5G	IMT-2020	5G	NR (New Radio)	5GC (5G Core)	5GS (5G System)
6G	IMT-2030	6G	-	-	-

International Telecommunication Union (ITU), The 3rd Generation Partnership Project (3GPP), Radio Access Network (RAN)



# DAY 1: 5G 네트워크 개요

## ❖ 5G and Beyond (Global Trend)

We are here					
1980s	1990s	2000s	2010s	2020s	2030s
<b>1G</b> Carry your phone around the country	<b>2G</b> Carry your phone around the world & text	<b>3G</b> Check e-mail from anywhere	<b>4G</b> Surf the web & watch video from anywhere	<b>5G</b> Connect to the digital fabric from anywhere	<b>6G</b> H2M & M2M automation anywhere
					
<b>Mobile Phone</b>	<b>Feature Phone</b>	<b>Smartphone</b>	<b>Smartphones, Hotspots, IoT Sensors</b>	<b>Smartphones, Hotspots, Cars, Robots, Drones, Mass IoT...</b>	<b>Intelligent Devices Mass M2M</b>
Mobile Voice Calls	SMS MMS	Mobile Internet Video Call	Streaming Video Voice over IP	4K/8K Video AR & 3D AI	Holographic Multi-sense Comms Real-time Intelligence
Data Rates: 19.2 kbps	384 kbps	43 Mbps	1 Gbps	20 Gbps	1 Tbps
Transmission: Analog	Digital	Digital	Digital	Digital	Digital
RAT: NMT, AMPS, TACS	GSM, GPRS, EDGE, IS-95	CDMA2000, UMTS	LTE, LTE-A, LTE-A Pro	NR SA & NSA	"ManyNets"
Multiple Access: FDMA	TDMA, CDMA	CDMA	OFDMA	OFDMA	Any approach is OK
Switching: Circuit	Circuit & Packet	Packet	Packet	Packet	AI-Enabled IP
Core Network: PSTN	PSTN	Packet	Packet	Virtual	Virtual
Roaming: National	Global	Global	Global	Global	Global

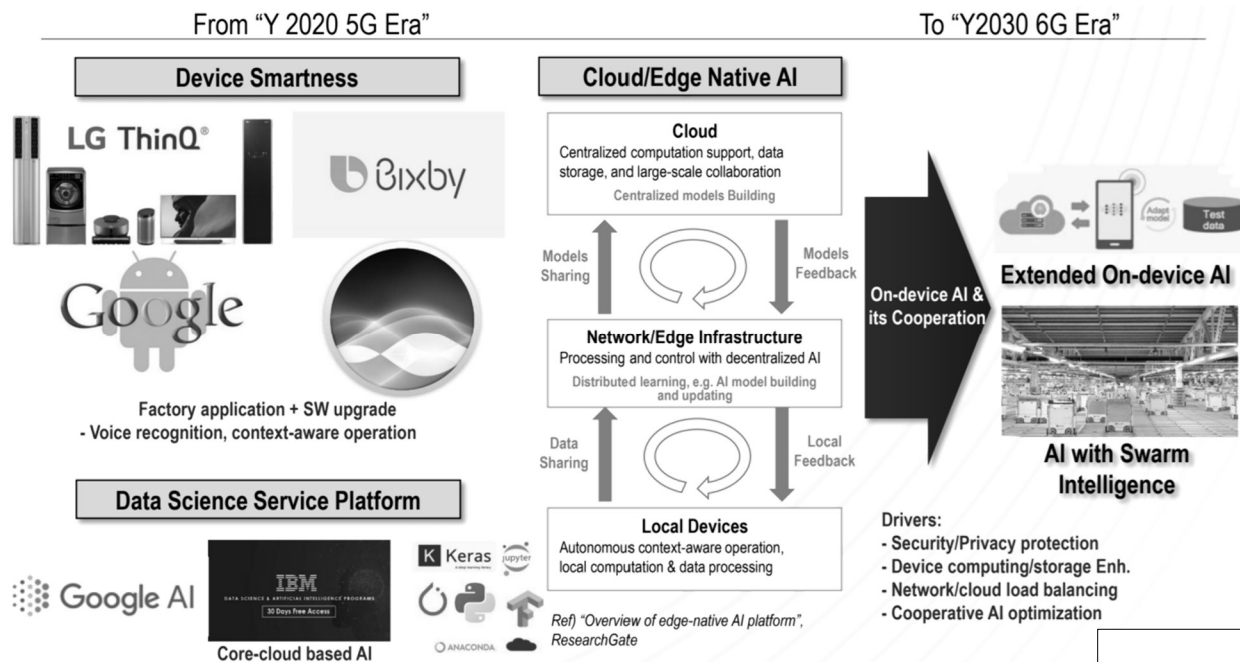
Source: Keysight



# DAY 1: 5G 네트워크 개요

## ❖ Y2030 Megatrends:

- 디바이스 스마트화 및 데이터 과학에 대한 AI는 클라우드/엣지 네이티브 AI 플랫폼에 의해 빠르게 확장하고, 온디바이스 AI와 연결성 기반 협력은 2030년경에 등장할 것으로 예상
- **Cloud/Edge Native AI**
  - Cloud
  - Network/Edge Infrastructure
  - Local Device
- **On-device AI & its Cooperation**
  - Extended On-device AI
  - AI with Swarm Intelligence



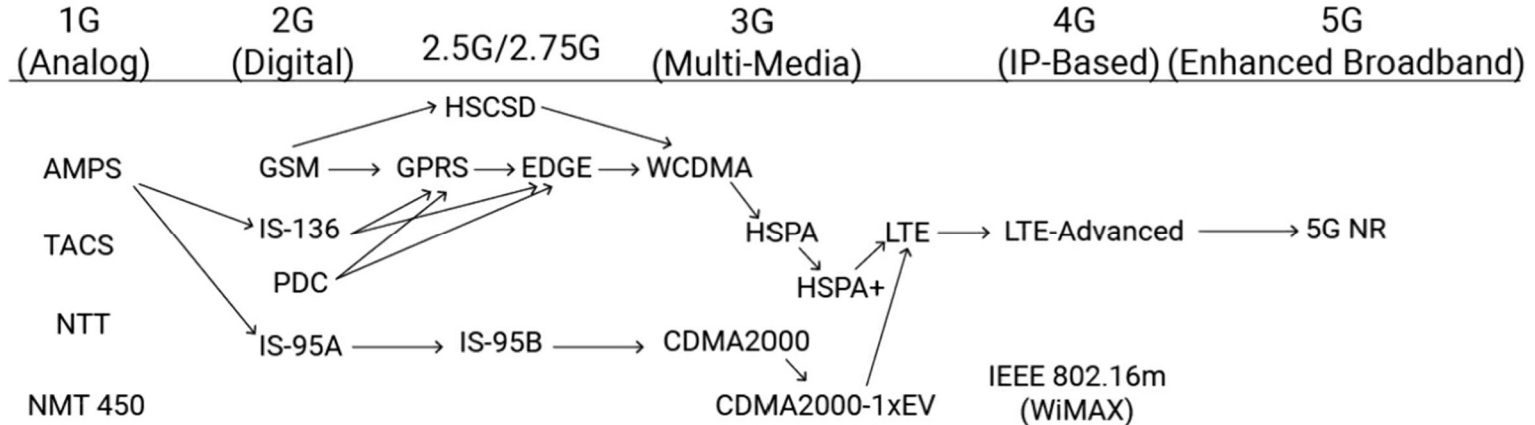
Source: LGE



# DAY 1: 5G 네트워크 개요

## ❖ 모바일 기술 발전과 3GPP

- 모바일은 통신 표준 개발 조직 컨소시엄인 3GPP(3rd Generation Partnership Project)가 LTE, 5G NR(5G New Radio) 등 전 세계에서 가장 널리 채택된 표준을 개발하고 유지 관리
- 상호 운용성 외에도 이전 버전과의 호환성을 유지하는 데 중점
- 엔터프라이즈는 Wi-Fi 액세스 포인트든 셀룰러 기지국이든 네트워킹 인프라를 구축하는 데는 많은 비용이 들 수 있으며, 사용자의 신기술 채택이 상당히 느릴 수 있다.

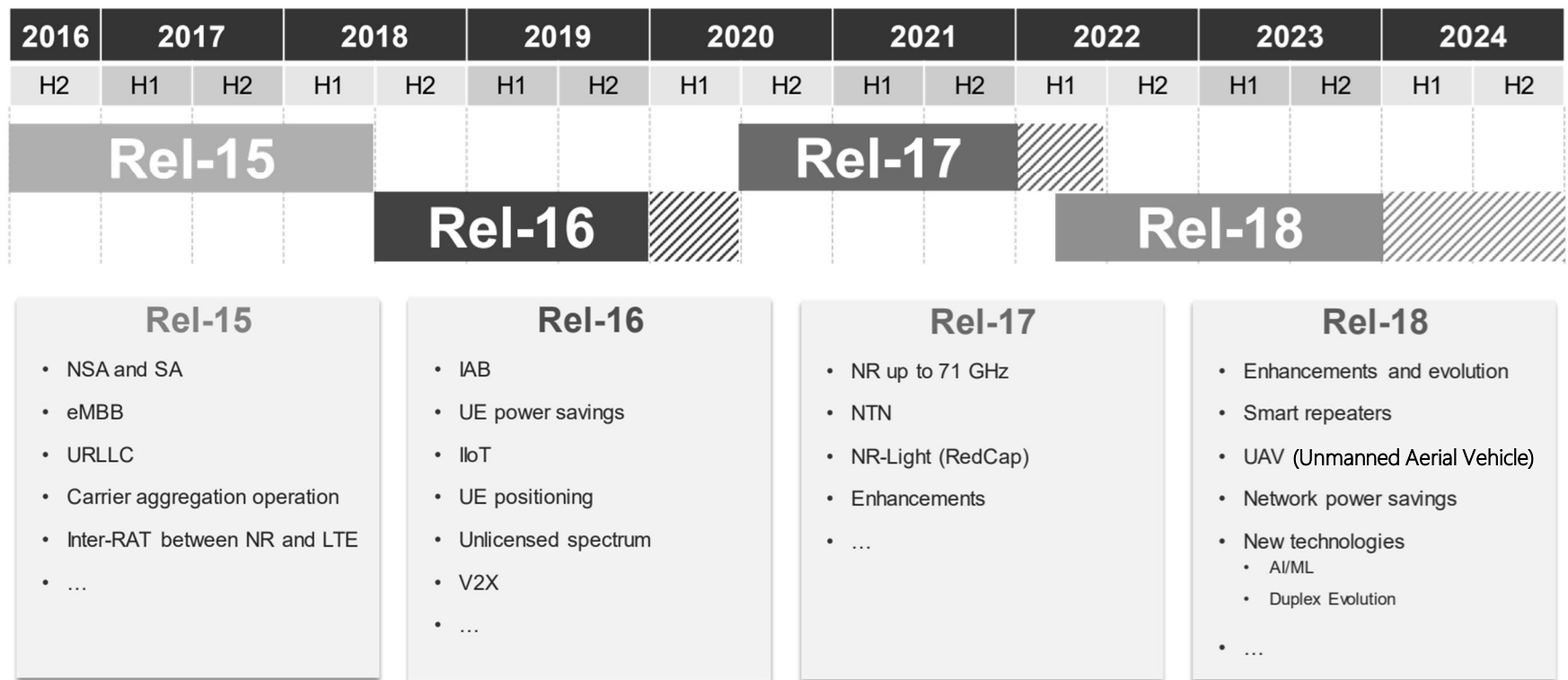


Source: Bejarano, Oscar. Wireless: A Total Beginner's Guide to Modern Wireless Communication Technologies (p. 245). Bitflip Media. Kindle Edition.



# DAY 1: 5G 네트워크 개요

## ❖ 3GPP NR Workplan



Source: KEYSIGHT





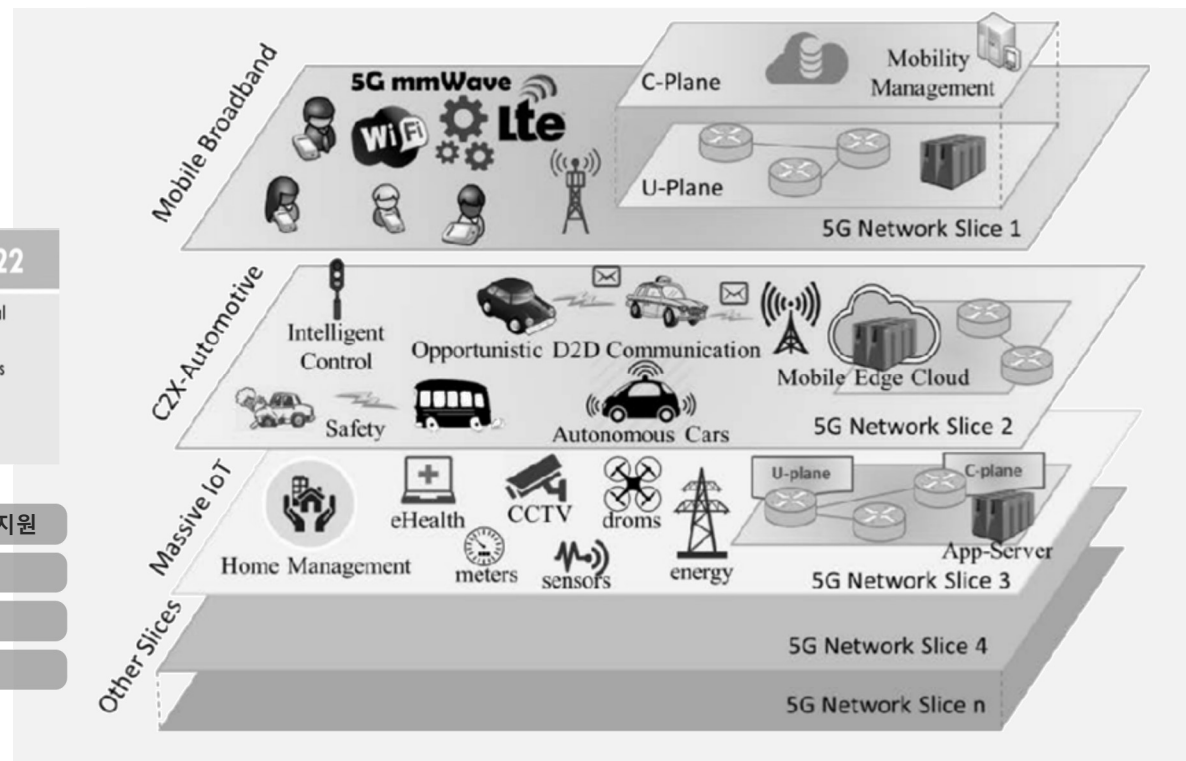
# DAY 1: 5G 네트워크 개요

## ❖ Basic slicing of 5G core network

- Wi-Fi, LTE, 5G

Release 15 - 2019	Release 16 - 2020	Release 17 - 2022
<ul style="list-style-type: none"> <li>• First NR ("New Radio") release.</li> <li>• 5G Vehicle-to-x service</li> <li>• Service Based Architecture (SBA)</li> </ul>	<ul style="list-style-type: none"> <li>• The 5G System - Phase 2</li> <li>• Industrial IoT</li> <li>• URLLC enhancements</li> <li>• 5G efficiency including Dynamic Spectrum Sharing (DSS)</li> </ul>	<ul style="list-style-type: none"> <li>• Support for non-terrestrial networks</li> <li>• Unmanned Aerial Systems</li> <li>• RAN Slicing</li> <li>• Edge Computing</li> </ul>

- 비저상네트워크 지원
- 무인 항공 시스템
- RAN 슬라이싱
- 에지 컴퓨팅



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020



# DAY 1: 5G 네트워크 개요

## ❖ 3GPP - Rel. 15

- MIMO
- MRDC
- DSS
- Coverage
- Others

### MIMO Enhancements



- Improved beamforming & beam steering
- Lowering overheads
- Benefits devices with multiple antennas

### MRDC(Multi-RAT Dual Connectivity)

#### MRDC



- Quickly turnoff unneeded radio on the device
- Improve battery life

### DSS (Dynamic Spectrum Sharing) 동적 스펙트럼 공유

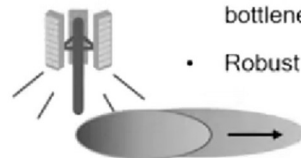
#### DSS



- Better cross-carrier scheduling, efficient signaling
- Manage increase in 5G device penetration

### 5G NR 기술 기반

### Coverage Extension



- Remove signaling bottleneck
- Robust signaling

### Many Others

- Multi-SIM,
- RAN Slicing
- Self Organizing
- QoE Enhancements
- UE power saving
- Lowering overheads

Source: Tantra Analyst



# DAY 1: 5G 네트워크 개요

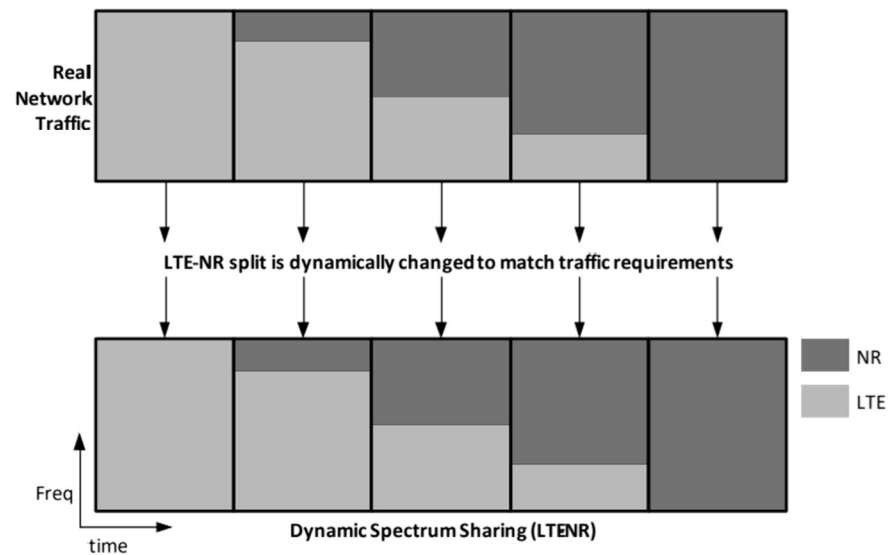
## ❖ DSS (Dynamic Spectrum Sharing)

### Dynamic

“Dynamic” is the key

- The split between LTE and NR can be changed at any time
- **Advantages:** Can adapt to traffic demands; rollout is possible with a software upgrade
- **Disadvantages:** Scheduling complexity

## Spectrum Sharing

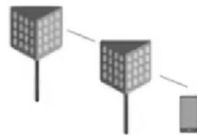


# DAY 1: 5G 네트워크 개요

## ❖ 3GPP - Rel. 16

- IAB
- Sidelink
- Small Data
- Positioning
- URLLC

### Integrated Access Backhaul (IAB)



- Improved performance
- More capability
  - More deployment flexibly
  - Enables cost-effective, mmWave densification

### Precise Positioning



- CM-level accuracy
- Using, RTT, TDoA, AoA, AoD
  - Lower latency & integrity for positioning
  - Critical for indoor use cases (e.g factories)

Use case / 산업 확대

### SideLink



- Expand V2X to public safety, emergency services & other handset-based apps
- Reduce power consumption & latency,
- Improve reliability

### Small Data Tx



- Connection in inactive state (w/o full call set-up)
- Reduce latency & save power
- Ideal for sensors & other IoT
- Useful for smartphone messaging apps

### URLLC on Unlicensed



- Improved spectral efficiency & capacity
- Hardened framework to support Time-sensitive-communication
- Time-synchronization enhancements

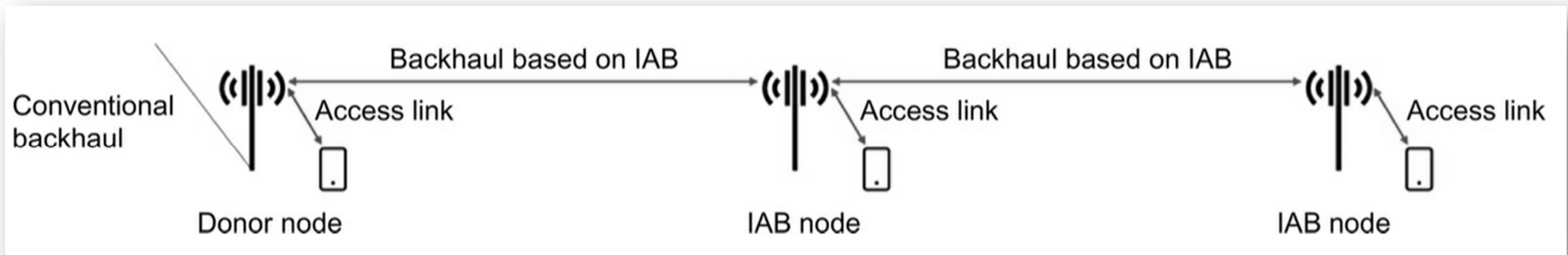
Source: Tantra Analyst



# DAY 1: 5G 네트워크 개요

## ❖ IAB (Integrated Access and Backhaul)

- WiFi등의 비면허 무선 기술을 5G에 수용
- Multi-RAT (Radio Access Technology)
- SDR (Software Defined Radio, 소프트웨어 정의 라디오)



Source: The Next Generation Wireless Access Technology Second, Edition Erik Dahlman Stefan Parkvall Johan Sköld

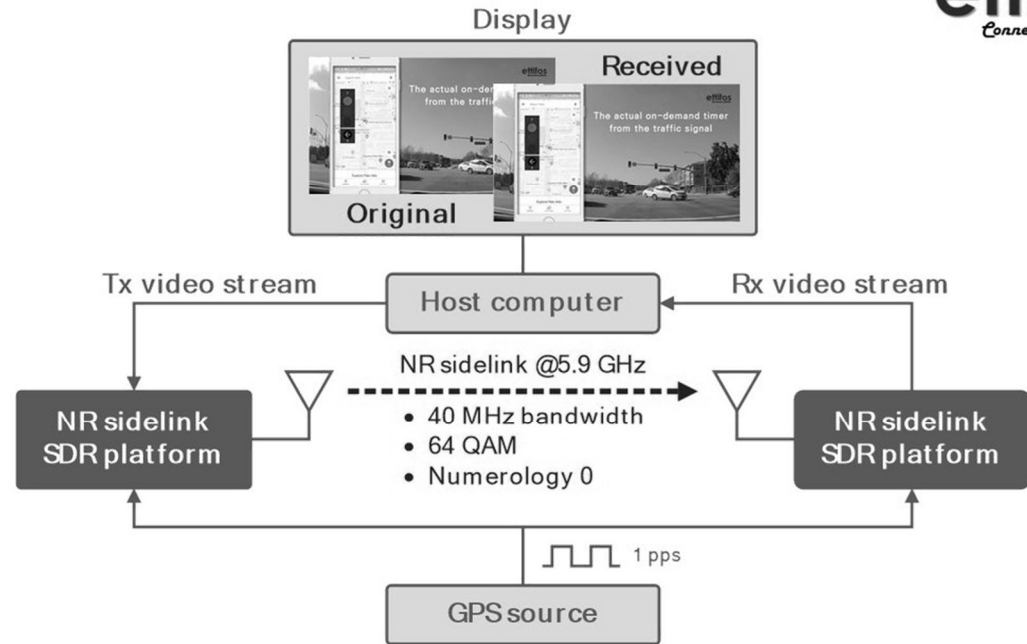


# DAY 1: 5G 네트워크 개요

## ❖ Sidelink

- 5G NR V2X sidelink solution (예)

Demo setup #1: Video sharing



Source: <https://twitter.com/EttifosKorea/status/1336549563314753537>

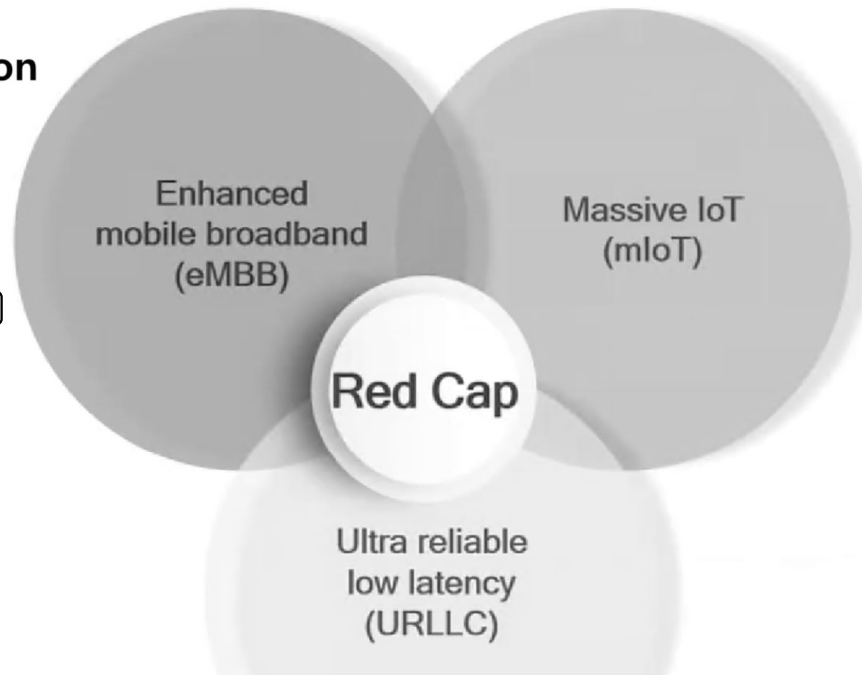


# DAY 1: 5G 네트워크 개요

## ❖ 3GPP - Rel. 17 (Red Cap)

- Low complexity
- Reduced Rx chains
- Smaller bandwidth
- Low modulation
- Half-duplex operation
- Lower cost

지속적 확대 / 개선



Low complexity

Reduced Rx chains (1 or 2)

Smaller bandwidths (20 MHz)

Lower modulation (64 QAM)

Half-duplex operation

Lower cost

For, wearables, IoT & other use cases/devices

Source: Tantra Analyst



# DAY 1: 5G 네트워크 개요

## ❖ 3GPP - Rel. 17 (New Concepts)

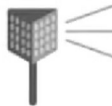
- AR/VR/XR
- mmWave
- Non-Terrestrial Network
- 5G MBS

### eXtended Reality (AR/VR/XR)



- Evaluate & Adopt 5G for XR
- Distributed architecture/Edge cloud
  - Device capabilities
  - Optimize latency, processing & Power

### mmWave (52.6 - 71 GHz)



- Expand mmWave
- Bandwidths up to 2 GHz
  - Even higher speeds/capacity
  - All kinds of spectrum

지속적 확대 / 개선

### Non-Terrestrial Network (NTN)



- Satellite NR, NB-IoT, LTE-M
- Accommodate higher latency, changing nodes etc.
  - Connect hard to reach areas, IoT outside cellular coverage  
E.g. Remote areas, Farms, Ships etc.

### 5G Multicast Broadcast (5G MBS)



- MBMS on NR
- Multicast (limited area) & Broadcast (full network) support
- Simplify operations, admn. & maintenance
- Public safety, FoTA, PTT, Live TV

Source: Tantra Analyst





# DAY 1: 5G 네트워크 개요

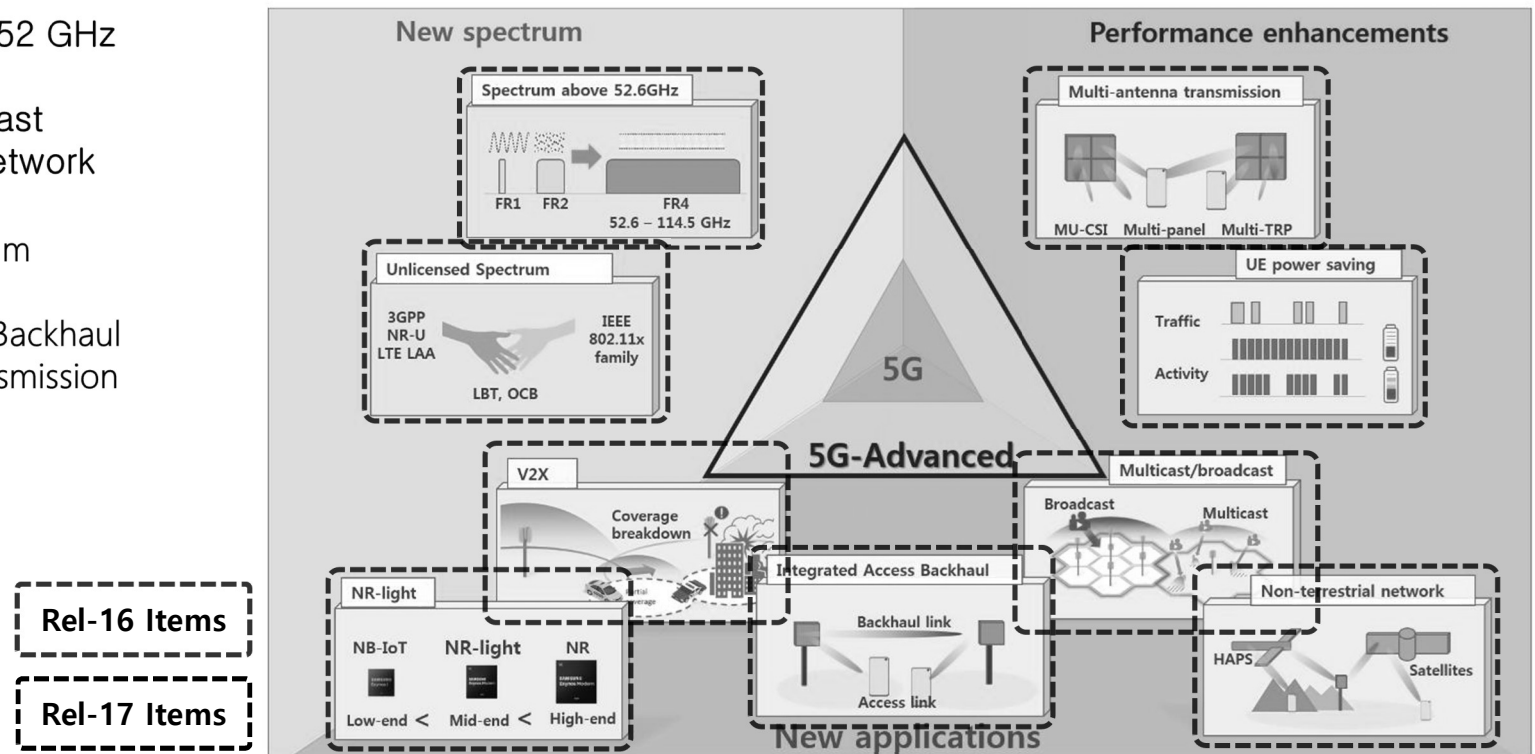
## ❖ 5G NR Revolution

### • Rel-16 Items

- Spectrum above 52 GHz
- NR-light
- Multicast/Broadcast
- Non-terrestrial network

### • Rel-17 Items

- Unlicensed Spectrum
- V2X
- Integrated Access Backhaul
- Multi-antenna transmission
- UE Power saving



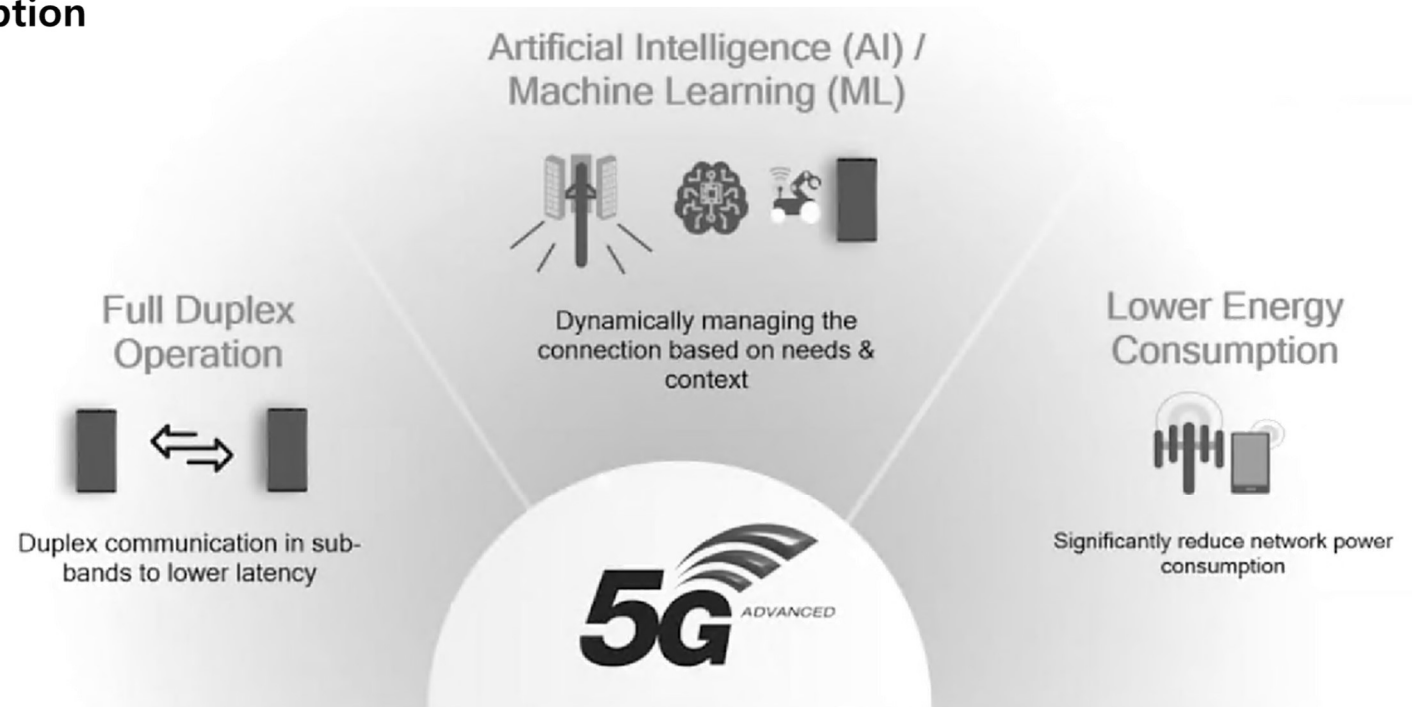
Source: KEYSIGHT



# DAY 1: 5G 네트워크 개요

## ❖ 3GPP - Looking forward – Rel. 18 & 5G Advanced

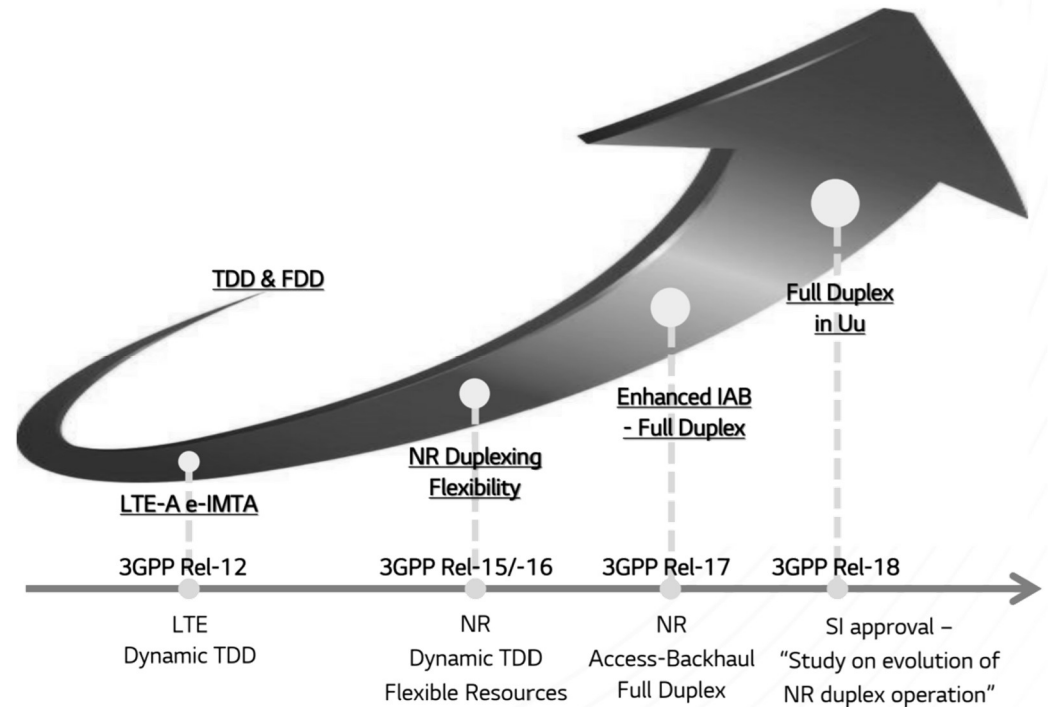
- Full Duplex Operation
- AI / ML
- Lower Energy Consumption



# DAY 1: 5G 네트워크 개요

## ❖ Full Duplex Radio:

- 3GPP's approaches for flexible duplexing technologies



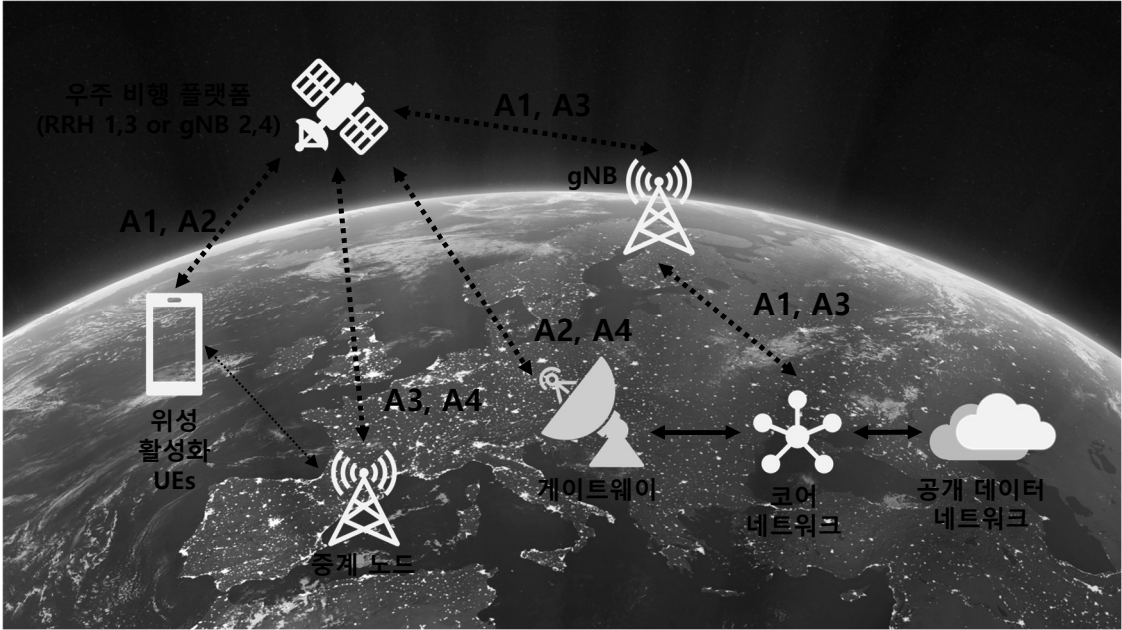
Source: LGE



# DAY 1: 5G 네트워크 개요

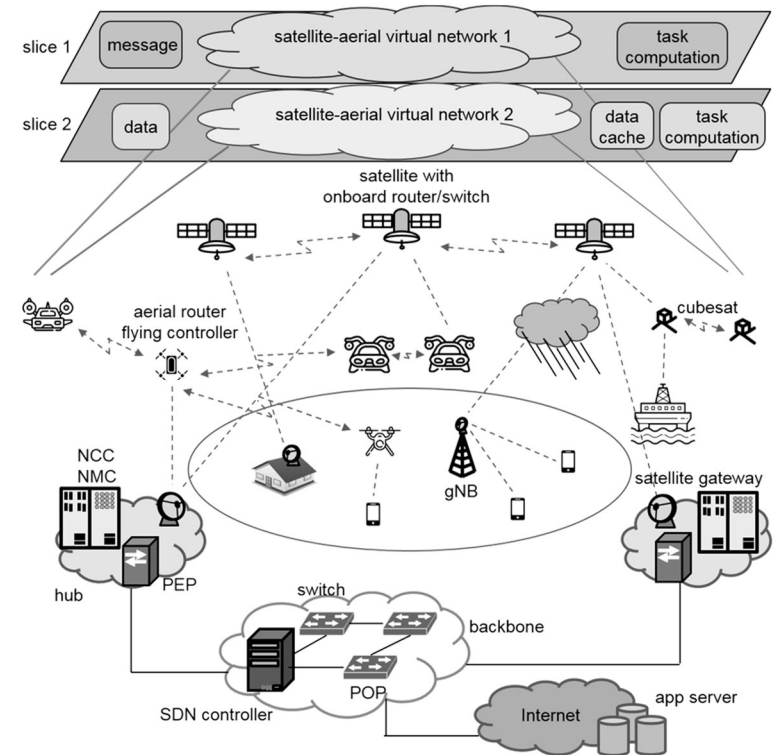
## ❖ 5G NR Revolution - Non-terrestrial network (NTN)

- A1. 지상의 gNB와 직접 사용자 액세스 링크 연결
- A2. 온보드 gNB를 통한 사용자 직접 액세스 링크
- A3. 지상에서 gNB와 액세스 링크를 제공하는 중계 노드
- A4. 온보드 gNB와 액세스 링크를 제공하는 중계 노드



# DAY 1: 5G 네트워크 개요

## ❖ Software-Defined Satellite Networks 소프트웨어 정의 위성망기술

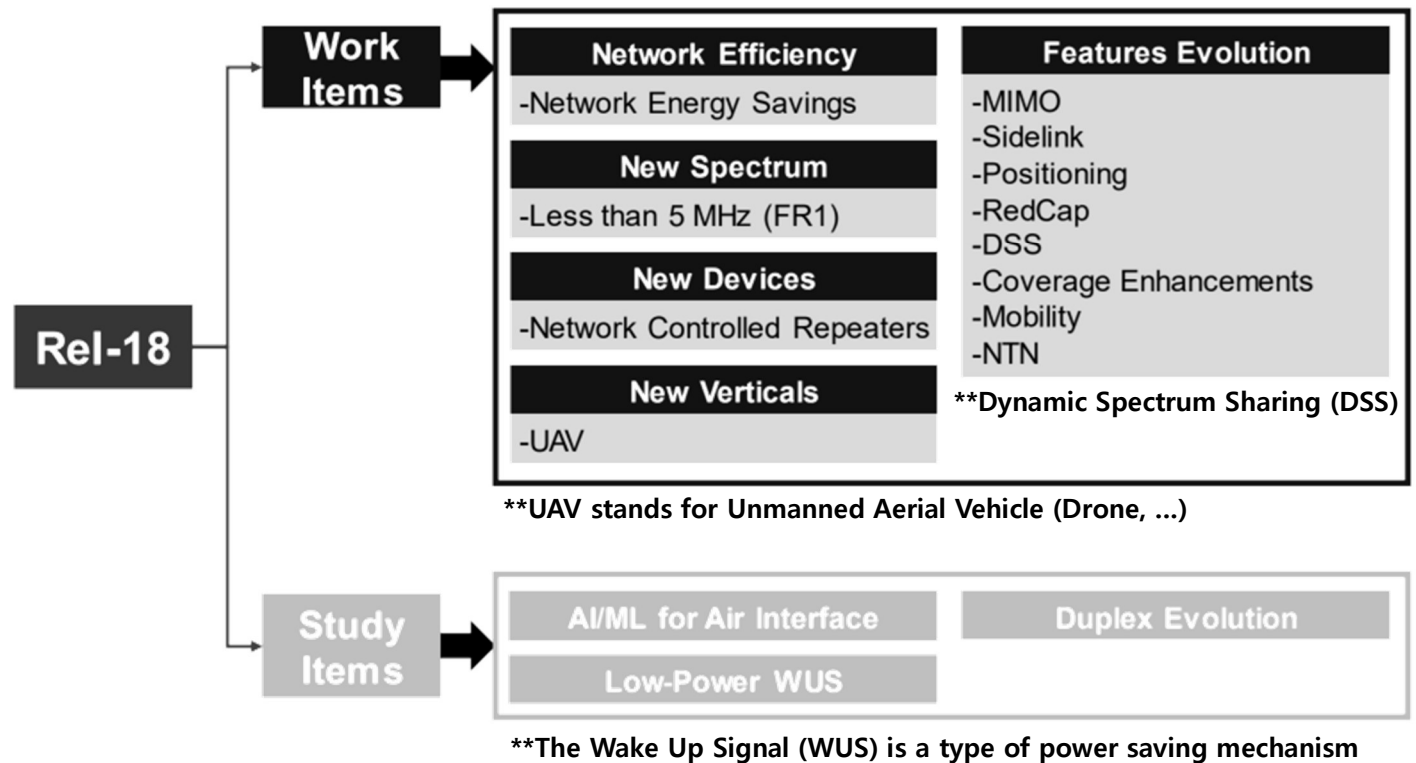


Source: Jihwan Choi @KAIST AE (Nov. 10, 2021)



# DAY 1: 5G 네트워크 개요

## ❖ Release-18 Content Summary



Source: KEYSIGHT



# DAY 1: 5G 네트워크 개요

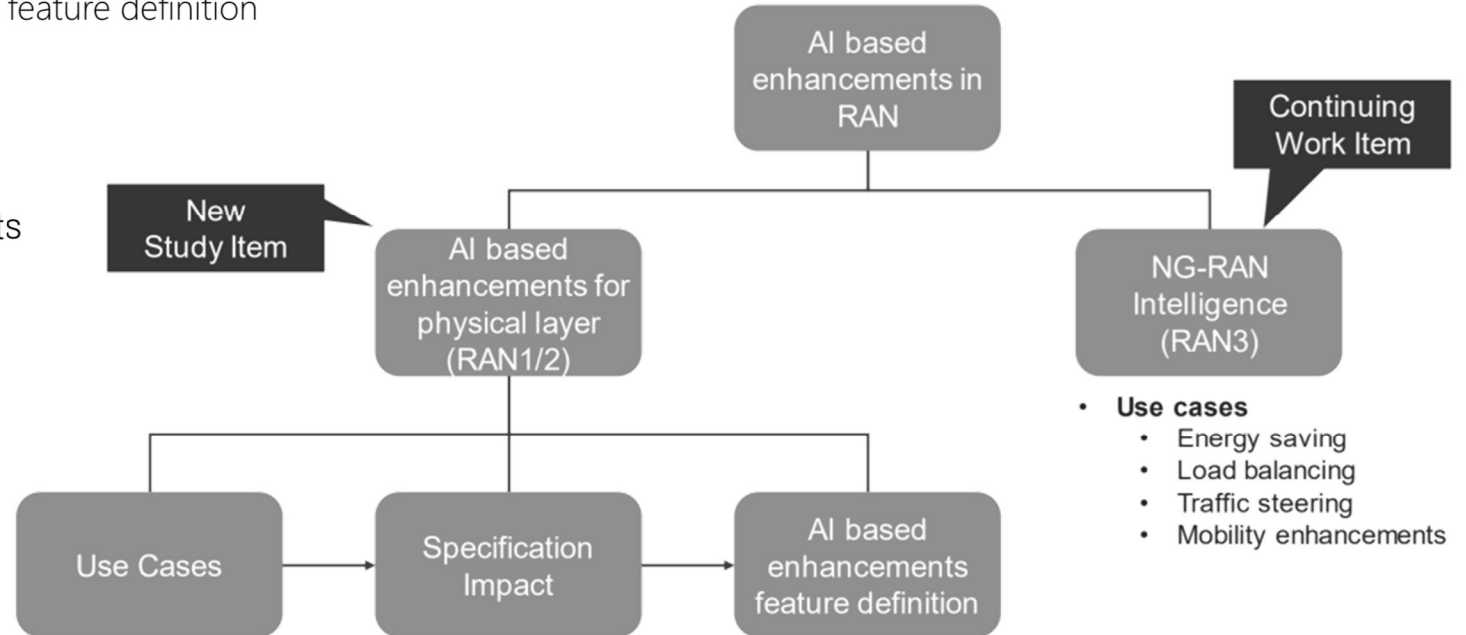
## ❖ AI/ML for the Air

### • AI based enhancements for physical layer(RAN1/2)

- Use cases
- Specification impact
- AI based enhancements feature definition

### • RAN3 Use cases

- Energy saving
- Load balancing
- Traffic steering
- Mobility enhancements



Source: KEYSIGHT



# DAY 1: 5G 네트워크 개요

## ❖ AI/ML for the Air Interface

- **Goal: enhanced performance or reduced complexity/overhead**

- AI/ML 기술을 활용한 미래 에어 인터페이스 사용 사례의 토대 마련

- **Areas to study**

- 기존 방식과의 성능 비교
- 잠재적인 사양 영향
- 후속 프로젝트에서 사용할 공통 AI/ML 프레임워크 식별
- AI/ML로 에어 인터페이스 기능의 성능을 개선할 수 있는 영역 식별

- **Use cases:**

- CSI 피드백 향상. 예: 오버헤드 감소, 정확도 향상, 예측
- 빔 관리: 시간 및/또는 공간 영역에서의 빔 예측을 통한 오버헤드 및 지연 시간 감소, 빔 선택 정확도 향상
- 위치 정확도 향상(예: 심한 NLOS 조건) \*\*NLOS stands for Non-Line Of Sight

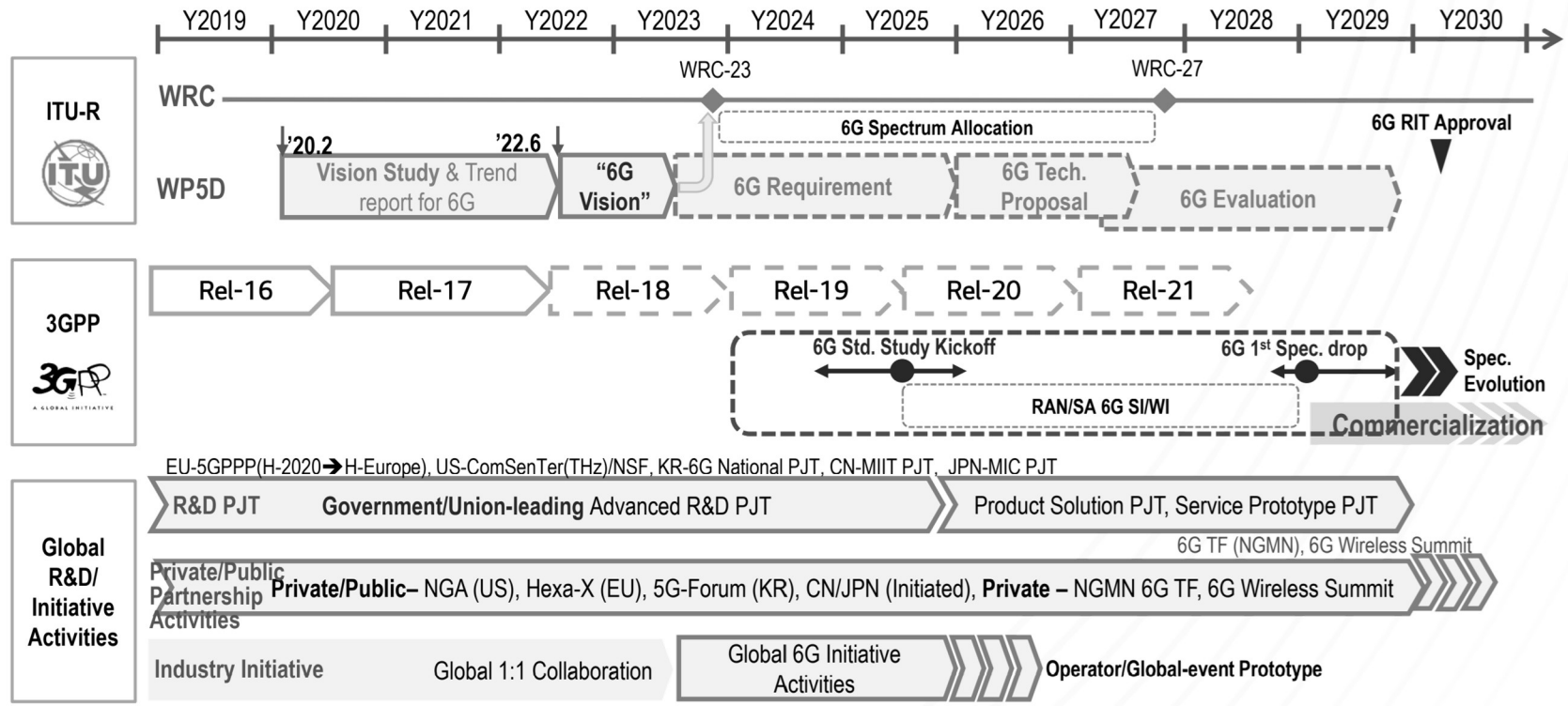
Source: KEYSIGHT





# DAY 1: 5G 네트워크 개요

❖ 6G: 2025년경부터 표준화되어 2028년 말 이후에 최초로 상용화될 예정



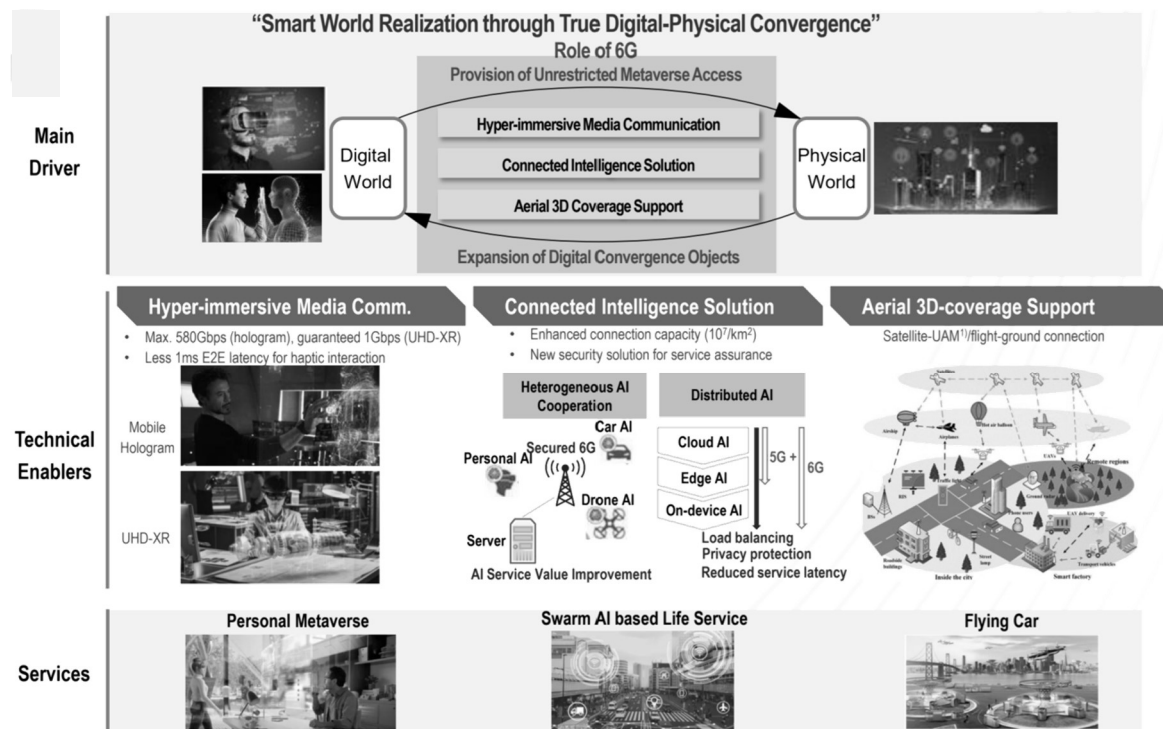
Source: Keysight 5G Summit 2022, Research Fellow, LG Electronics, Inc., Jaehoon Chung



# DAY 1: 5G 네트워크 개요

## ❖ 6G Vision & Driving Forces (LGE 예):

- 초 몰입형 미디어 커뮤니케이션.
- 커넥티드 인텔리전스 솔루션
- 공중 3D 컨버전스 지원



Source: LGE



# DAY 1: 5G 네트워크 개요

## ❖ 6G Enabling Technologies (LGE 예):

### • Continuous adaptation with global technical trends

- ✓ 무선 전송 기술
- ✓ 네트워크 아키텍처 / 솔루션

#### Radio Transmission Technologies

<b>New Spectrum Utilization</b>	<b>Terahertz radio communication</b> , Dynamic spectrum sharing
<b>Spectral Efficiency Enhancement</b>	<b>Full duplex radio</b> , AI/ML integrated radio, Ultra massive MIMO/BF, New waveform/channel coding
<b>Radio Coverage Extension/Improvement</b>	3D radio coverage (UAV/UAM/Flight/Satellite), Intelligent reflection surface, mmWave enhancement
<b>Radio Solution Convergence</b>	Joint communication & sensing, Mobile OWC HD positioning technology



#### Network Architecture / Solutions

<b>Flexible Network Architecture</b>	<small>Mesh/P2P/Mobile-IAB</small> New network topology & architectural evolution Seamless mobility, Distributed cloud & computing
<b>Secure and Green Network Solution</b>	Brand new security (PQC, Homomorphic), Network energy saving

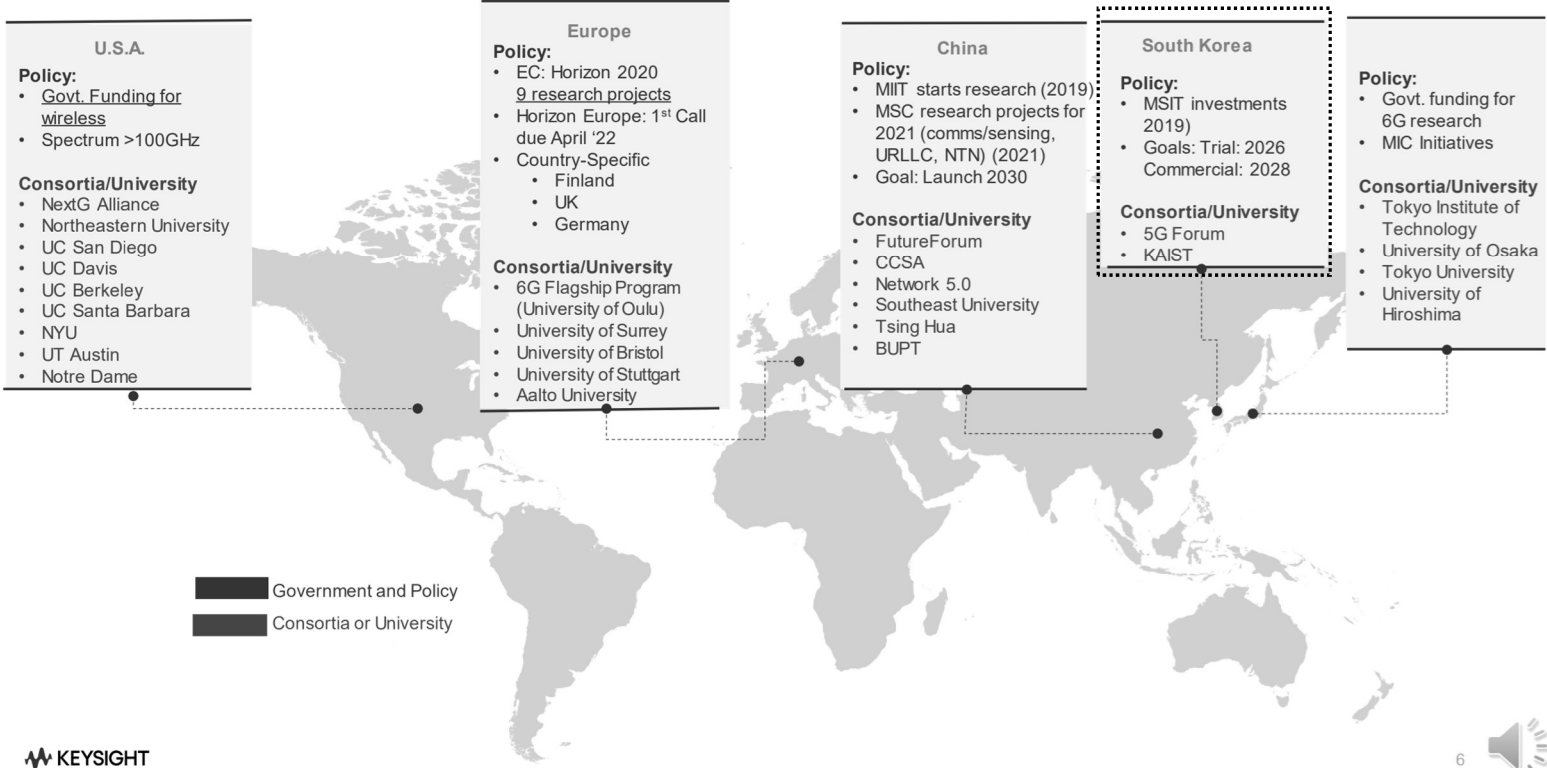


Source: LGE



# DAY 1: 5G 네트워크 개요

## ❖ 6G Action Worldwide



Source: Keysight



# DAY 1: 5G 네트워크 개요

❖ 6G는 연구 개발 단계이며 5G보다 빠르고 스마트하며 효율적일 것으로 예상된다.

- **속도:** 6G는 5G보다 100배 빠른 모바일 데이터 속도를 제공하여 초당 최대 100기가비트로 예상하며, 95GHz ~ 3THz 주파수에서 5G보다 1,000배 빠른 속도를 제공하는 예를 볼 수 있음
- **신뢰성:** 6G는 특히 고밀도 지역과 원격 위치에서 5G보다 더 안정적이고 일관된 연결을 제공하고 홀로그램 통신, 자율 주행, 두뇌-컴퓨터 인터페이스와 같은 초저지연 애플리케이션을 지원을 예상
- **커버리지:** 6G는 지상 네트워크를 넘어 위성 네트워크, 공중 네트워크, 수중 네트워크까지 네트워크 커버리지를 확장할 것이며, 향후 몇 년 동안 연결되는 디바이스의 수가 증가함에 따라 5G보다 평방 킬로미터당 10배 더 많은 디바이스를 연결할 것으로 예상된다.

❖ 현재 연구와 예측에 근거한 5G와 6G의 잠재적 차이점이며 6G 기술을 개발하고 배포하는 데에는 많은 불확실성과 과제가 남아 있다.



# DAY 1: 5G 네트워크 개요

## ❖ 6G는 현실화되기까지 다음과 같은 어려움을 해결 하는 것이 필요

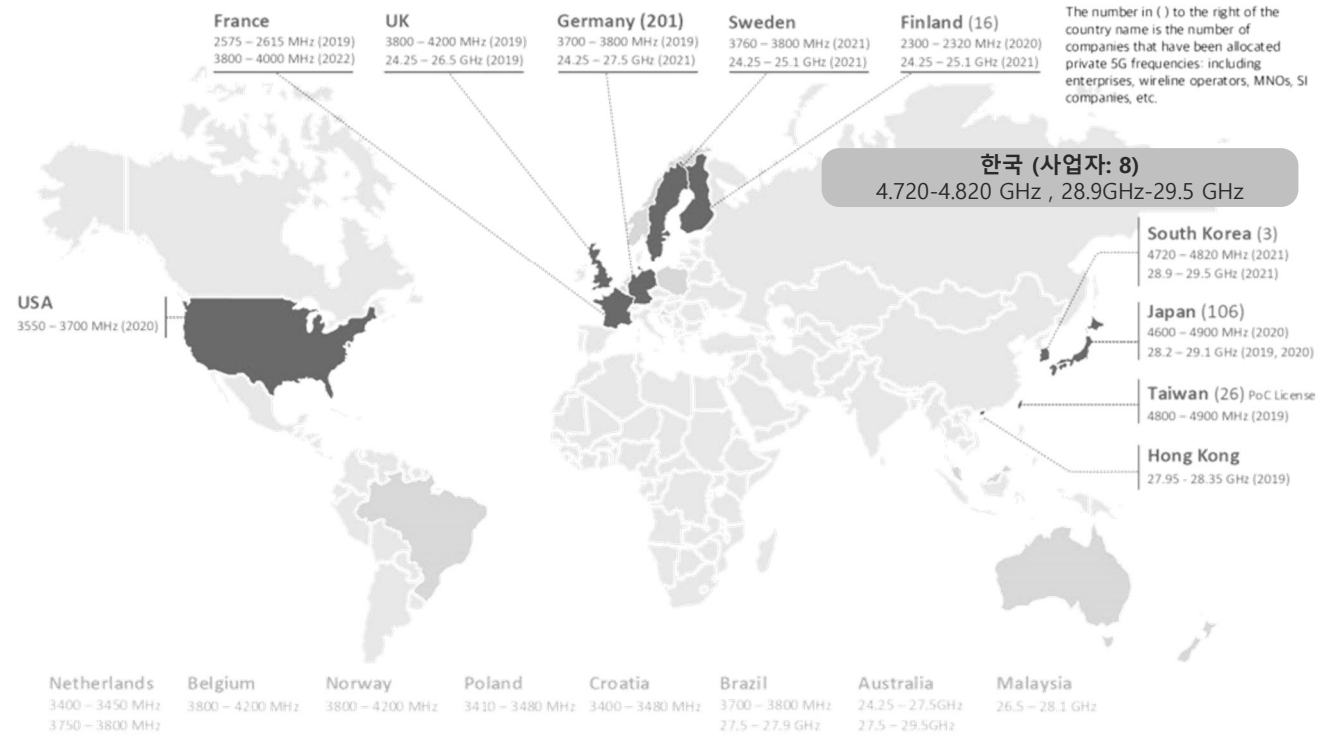
- **스펙트럼:** 6G는 높은 데이터 속도와 대규모 연결을 지원하기 위해 많은 스펙트럼이 필요합니다. 그러나 현재 할당된 스펙트럼은 6G에 충분하지 않을 수 있으며, 새로운 스펙트럼 대역에 액세스하는 데 관련된 간섭, 규제 및 비용 문제 해결이 필요하다.
- **로컬 통신:** 6G는 5G보다 로컬 통신 및 네트워킹에 더 많이 의존하게 되므로 디바이스가 서로 직접 또는 중계 노드나 메시 네트워크를 통해 통신해야 한다. 따라서 효율적이고 안전한 로컬 통신을 보장하기 위해 새로운 프로토콜, 알고리즘 및 아키텍처가 필요하다.
- **환경:** 6G는 비, 안개, 먼지 등과 같은 환경 요인에 민감한 매우 높은 주파수에서 작동합니다. 이러한 요인으로 인해 신호 감쇠, 반사, 산란 및 흡수가 발생하여 6G의 성능이 저하될 수 있다. 따라서 6G는 변화하는 환경에 적응하고 빔포밍, 지능형 반사 표면, 홀로그램 라디오<sup>45</sup>와 같은 기술을 사용해야 한다.
- **애플리케이션:** 6G는 지연 시간, 신뢰성, 보안 및 개인 정보 보호 측면에서 매우 까다로운 요구 사항을 가진 새로운 애플리케이션을 가능하게 할 것이다. 예를 들어 홀로그램 통신에는 밀리초 미만의 지연 시간과 초당 테라비트 데이터 속도가 필요하고, 자율 주행에는 오류율이 낮고 매우 안정적인 통신이 필요하며, 뇌-컴퓨터 인터페이스에는 높은 보안과 개인정보 보호가 요구될 것이다. 이러한 애플리케이션은 6G에 새로운 기술적, 윤리적 과제를 제기할 것이다.



# DAY 1: 5G 네트워크 개요

## ❖ Current status of commercialization of private 5G frequencies in countries around the world

이음5G (5G 특화망)



June 07, 2022 | By Harrison J. Son (son@netmanias.com)

As of 2022.06.07 - Countries preparing to commercialize private 5G frequencies

Source: <https://www.netmanias.com/en/?m=view&id=oneshot&no=15513> , <https://www.netmanias.com/ko/private-5g/major-players/1777/>

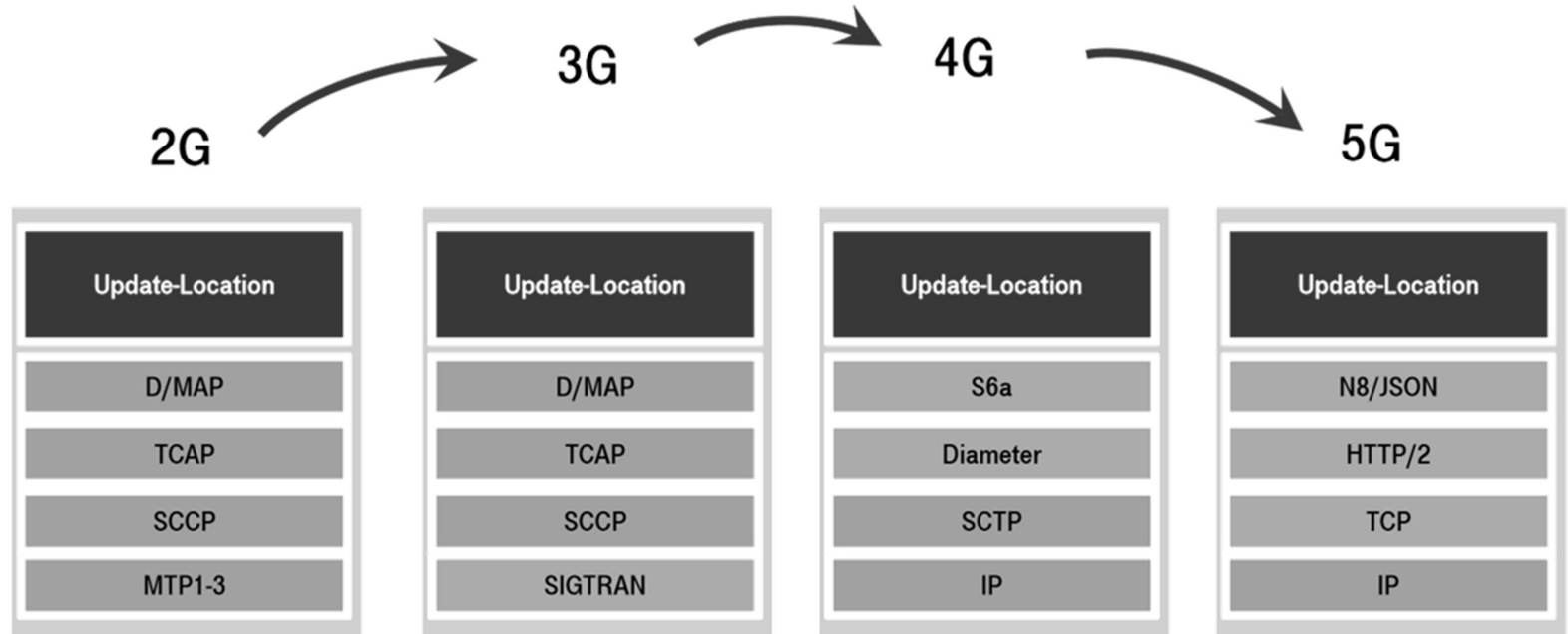


# DAY 1: 5G 네트워크 개요

❖ 5G Core procedures run on top of web technologies

## PROTOCOL EVOLUTION

EXAMPLE: UPDATE LOCATION REQUEST



Source: <https://devopedia.org/5g-service-based-architecture#further-reading>



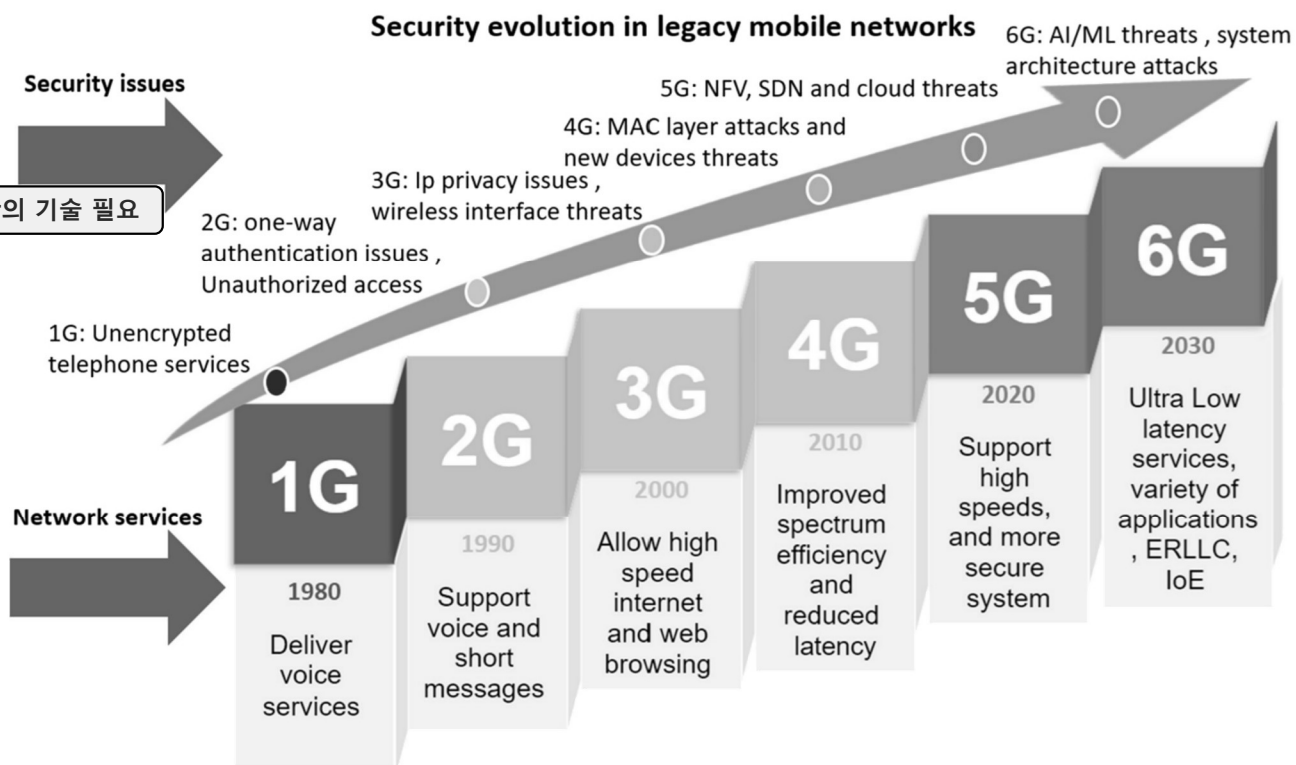


# DAY 1: 5G 네트워크 개요

## ❖ 1G에서 미래 6G로 예상되는 모바일 통신의 보안 진화

- 4G: MAC layer / new devices
- 5G: NFV/SDN/Cloud
- 6G: AI/ML

5G Networks 보안을 위해 NFV/SDN/Cloud 기반의 기술 필요

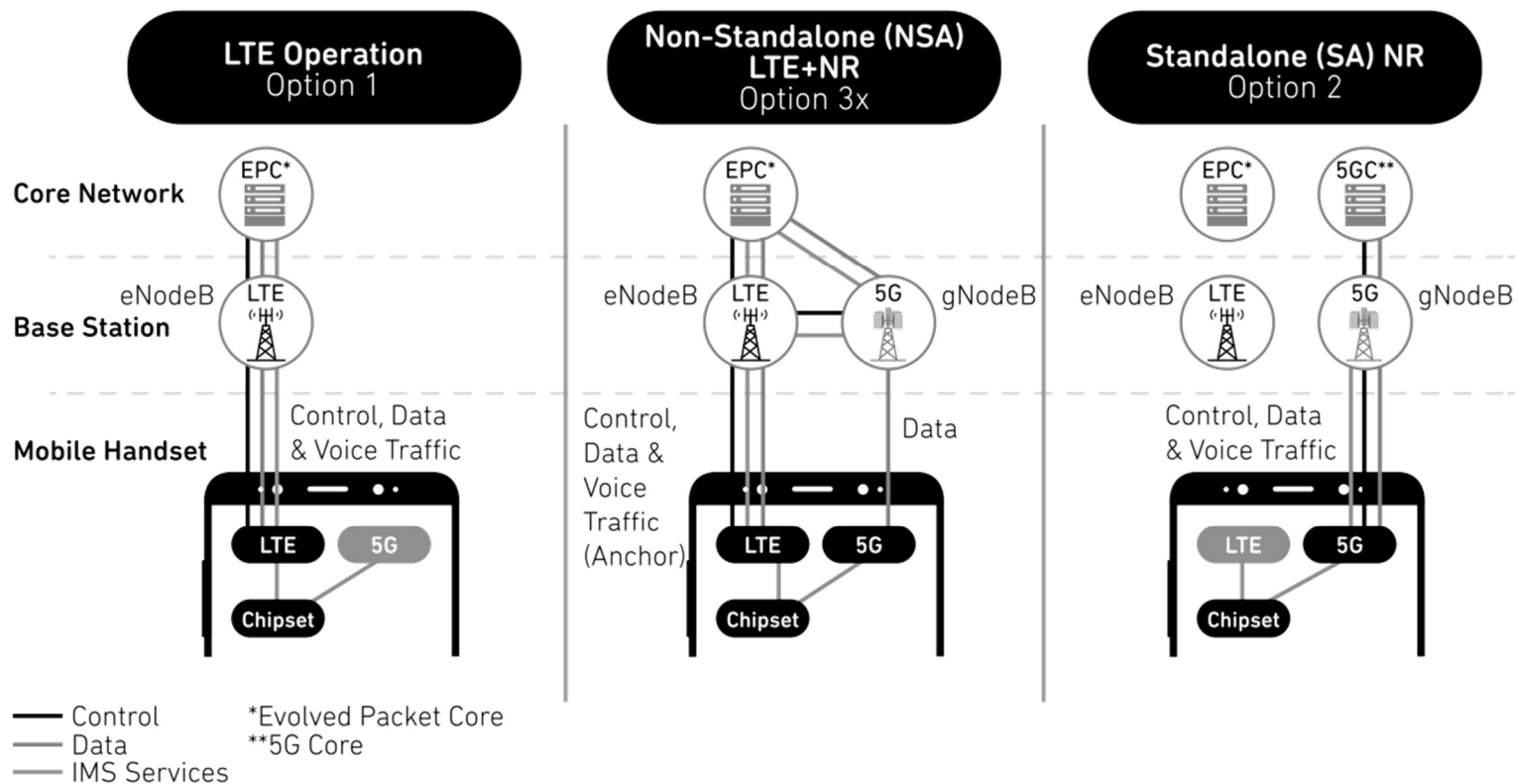


Source: 'Security Requirements and Challenges of 6G Technologies and Applications' Shima A. Abdel Hakeem, Hanan H. Hussein and HyungWon Kim, mdpi



# DAY 1: 5G 네트워크 개요

## ❖ 5G 구축의 점진적 전환.



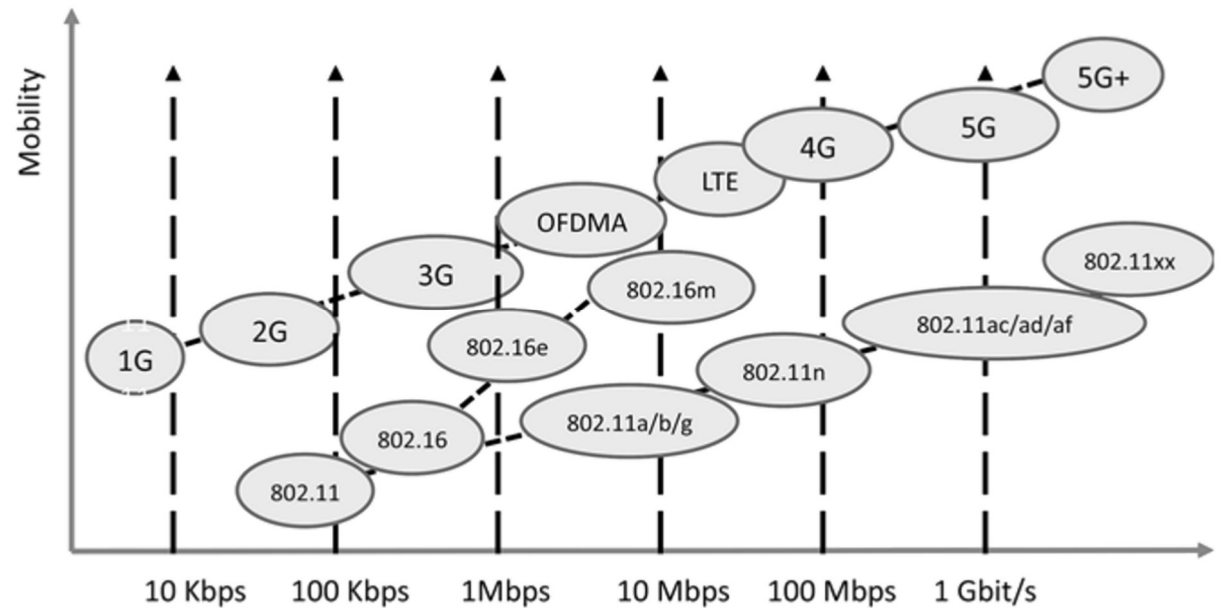
Source: 5G RF, 2nd Qorvo Special Edition, by David Schnauer, Tuan Nguyen, Ben Thomas, Alexis Mariani, Paul Cooper, Bror Peterson, Phil Warder



# DAY 1: 5G 네트워크 개요

## ❖ 무선 네트워크의 발전 (Wi-Fi 와 5G)

- The different generations of wireless networks



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020



# DAY 1: 5G 네트워크 개요

## ❖ Summary of 802.11 Standard Amendments.

Standard / Amendment	Release (Year)	Freq. Band (GHz)	Max. Data Rate	Channel Width (MHz)	Maximum Modulation	MIMO Capabilities
802.11	1997	2.4	2 Mbps	20	QPSK	--
802.11a	1999	5	54 Mbps	20	64-QAM	--
802.11b	1999	2.4	11 Mbps	20	QPSK	--
802.11g	2003	2.4	54 Mbps	20	64-QAM	--
802.11n	2009	2.4/5	600 Mbps	20/40	64-QAM	SU-MIMO (4x4)
802.11ac	2013	5	6.93 Gbps	20/40/80/ 160	256-QAM	MU-MIMO (8x8) <sup>†</sup>
802.11ax	2021	2.4/5/6	9.6 Gbps	20/40/80/ 160	1024-QAM	MU-MIMO (8x8) <sup>‡</sup>
802.11be	Exp. 2024	2.4/5/6	46.1 Gbps	20/40/80/ 160/320	4096-QAM	MU-MIMO (16x16)

Wi-Fi 7

<sup>†</sup> Up to four simultaneous users and downlink-only MU-MIMO

<sup>‡</sup> MU-MIMO in both uplink and downlink

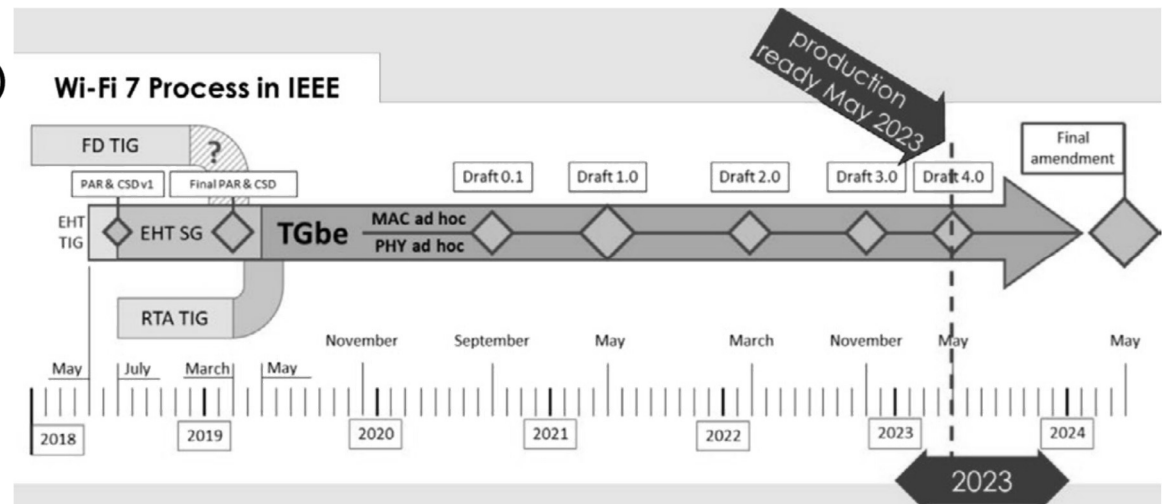
Source: Bejarano, Oscar. Wireless: A Total Beginner's Guide to Modern Wireless Communication Technologies (p. 299). Bitflip Media. Kindle Edition.



# DAY 1: 5G 네트워크 개요

## ❖ Wi-Fi 7's key feature set

- Multi-link aggregation
- Bigger channels
- Multi-band congestion avoidance
- Multi-AP data transfer
- Multi-AP mobility
- Roaming compatibility
- Enhanced sensing
- Restricted Targeted Wait Time (RTWT)



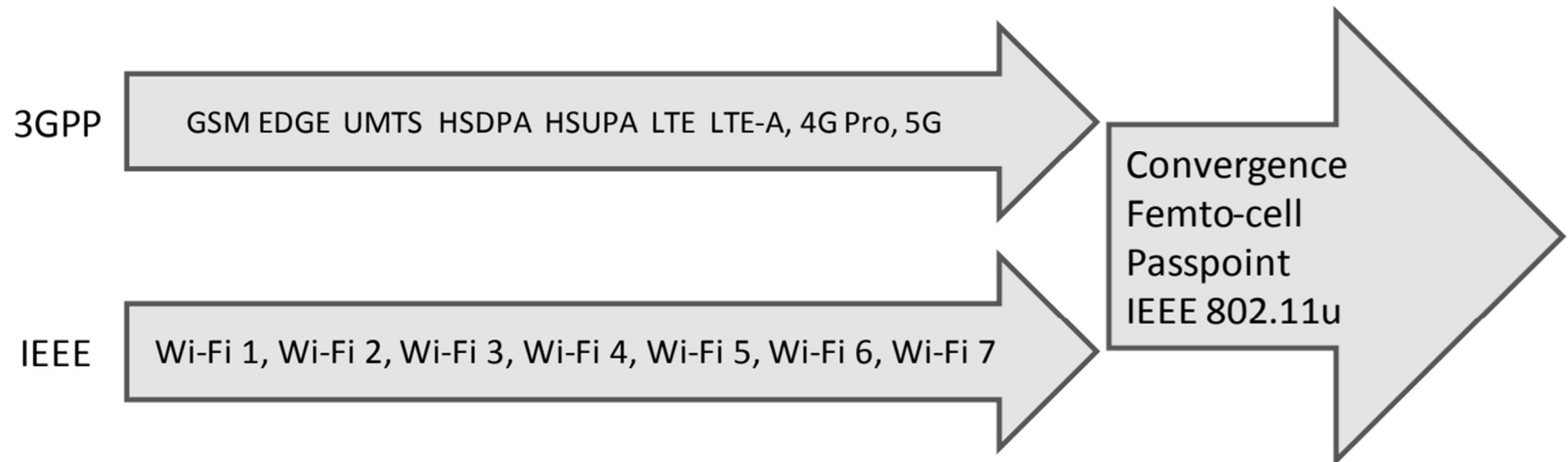
Source: Bejarano, Wi-Fi 7 – WHAT IS IT ALL ABOUT?, Whitepaper, Amdocs Networks



# DAY 1: 5G 네트워크 개요

## ❖ 무선 기술 융합 (Wi-Fi 와 5G)

- The two major wireless solutions and their convergence
- 이기종 네트워크간 심리스 핸드오버 기술 표준화
- 노트북이나 스마트폰 등 통신 기기들이 무선랜 등에 연결 할 수 있는 IEEE 802.11의 기술 표준



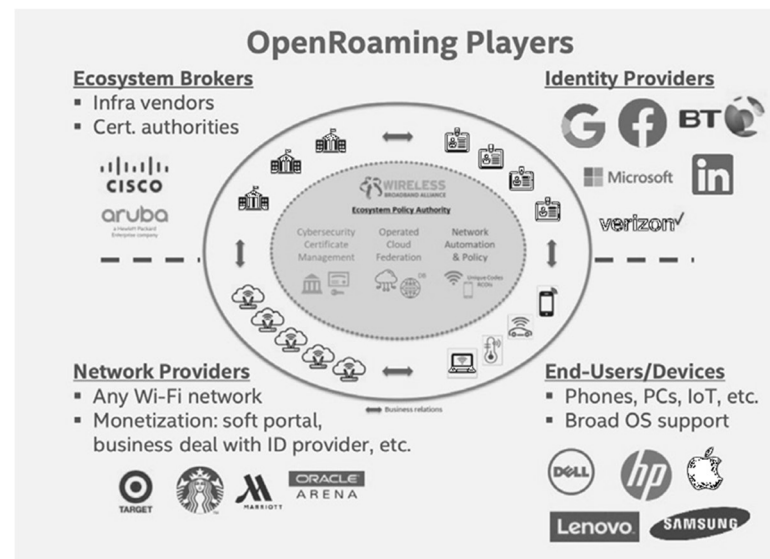
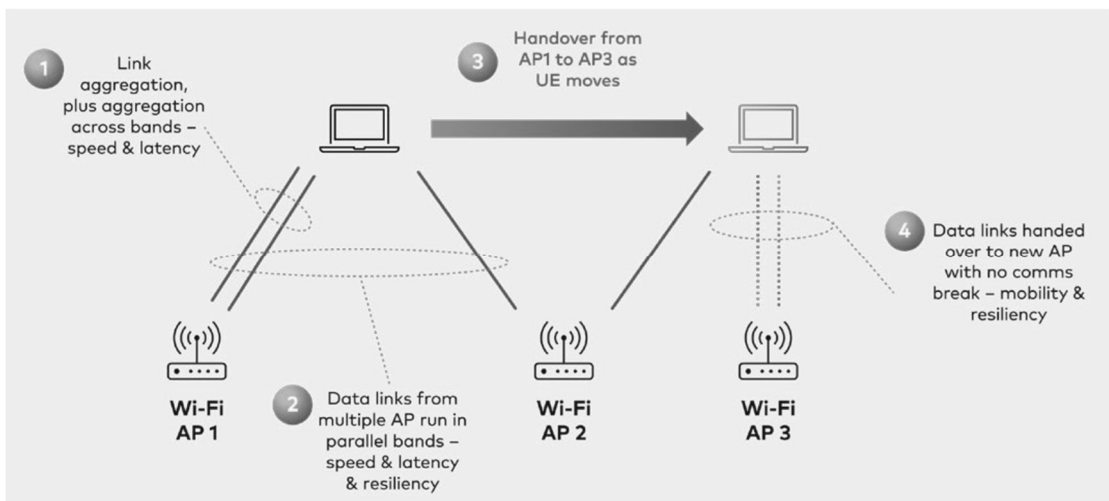
Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020



# DAY 1: 5G 네트워크 개요

## ❖ Wi-Fi 7's impact on mobile

- 모바일이 실내 엔터프라이즈 비즈니스 및 가정 소비자 시장에서 Wi-Fi를 대체할 가능성은 거의 없다.
- 소규모 공장, 소매점 및 소규모 실외 지역에서 Wi-Fi와 모바일 기반 솔루션 간의 경쟁이 치열해질 것으로 예상
- 더 넓은 야외 공간에서는 모바일이 지배적일 것으로 예상된다.



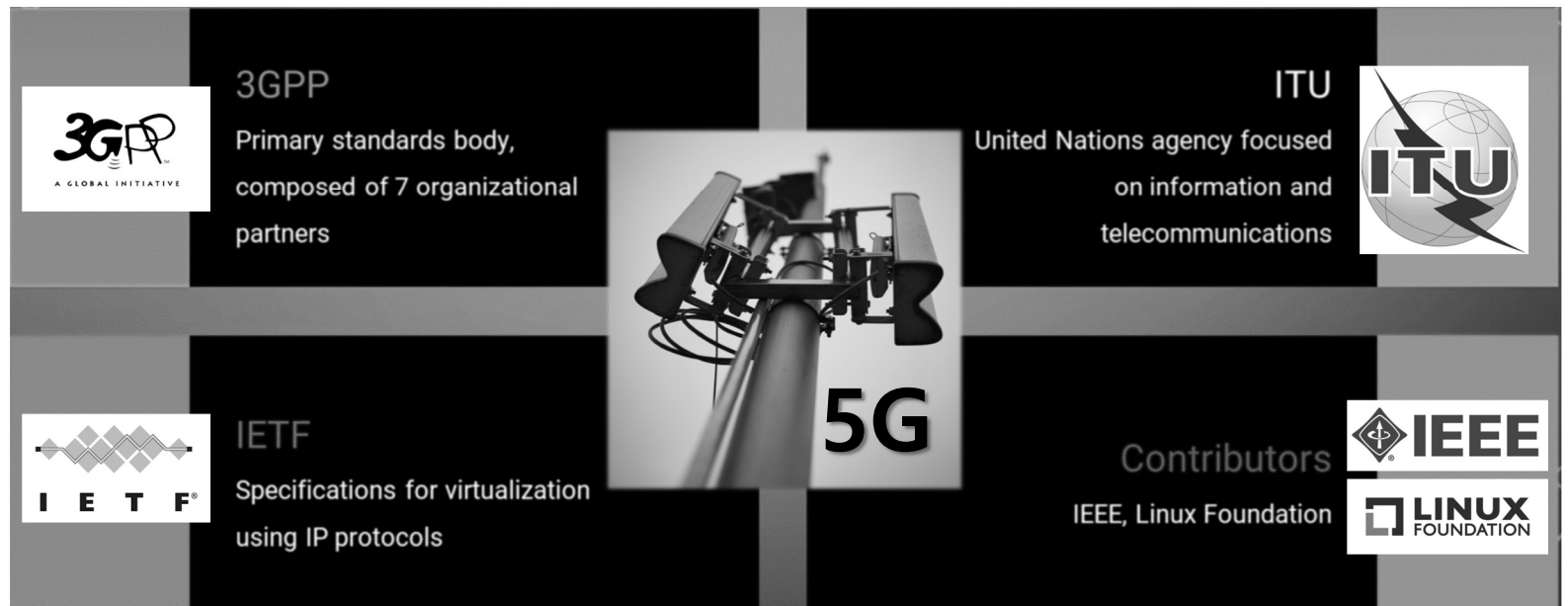
Source: Bejarano, Wi-Fi 7 – WHAT IS IT ALL ABOUT?, Whitepaper, Amdocs Networks



# DAY 1: 5G 네트워크 개요

## ❖ 5G 무선 표준 기관


- 3GPP
- ITU
- IETF
- IEEE
- 리눅스 재단
- 기타





# DAY 1: 5G 네트워크 개요

## ❖ Open 5G Network (예): 'FreedomFi'




**FreedomFi Outdoor Bundle with Nova430H**

Join the People's 5G network! Get a plug-and-play hotspot bundle direct from FreedomFi including a FreedomFi gateway, a Powered by FreedomFi Baicells Nova430H outdoor CBRS small cell and a FreedomFi beta physical SIM card. Earn MOBILE rewards for providing cellular coverage.

**\$2,499**

Buy Now




**FreedomFi High-power Outdoor Bundle**

The FreedomFi High-power Outdoor CBRS Bundle includes the core components needed to set up a Helium 5G CBRS small cell hotspot and connect a mobile device to test and use the cellular network. The FreedomFi Gateway will mine HNT for providing Lora coverage and together with the Baicells Nova436H can mine the new MOBILE token.

**\$5,699**

Buy Now



**FreedomFi 2 Nova430H Outdoor Bundle**

Set up expanded coverage with 2 directional CBRS small cells pointed in different directions for greater MOBILE earning potential. This plug-and-play hotspot bundle direct from FreedomFi includes a FreedomFi gateway, 2 Powered by FreedomFi Baicells Nova430H outdoor CBRS small cells and a FreedomFi beta physical SIM card.

**\$3,899**

Buy Now



**CBRS Private LTE Starter Kit**

- ..... Accelleran E1012 250mw Indoor/Outdoor Base Station
- ..... 2x 10 Dbi Direct Attach Omni Antennas
- ..... PoE Injector and CAT6 Cables
- ..... Indoor / Outdoor Mounting Solution
- ..... GPS Antenna
- ..... FreedomFi Gateway based on Magma
- ..... Sercomm CBRS USB Dongle
- ..... SIM Cards

Source: <https://freedomfi.com/catalog/>



# DAY 1: 5G 네트워크 개요

## ❖ 번들키트 (예): 'Baicells' \$8,999

- 1 Nova846
- 5 ATOM OD15 CPEs
- 1 DC/CA License Key
- 5 SNAP PoE Routers (WiFi)
- 10 SIM cards



Source: <https://promo.baicells.com/2023bundlekit/>

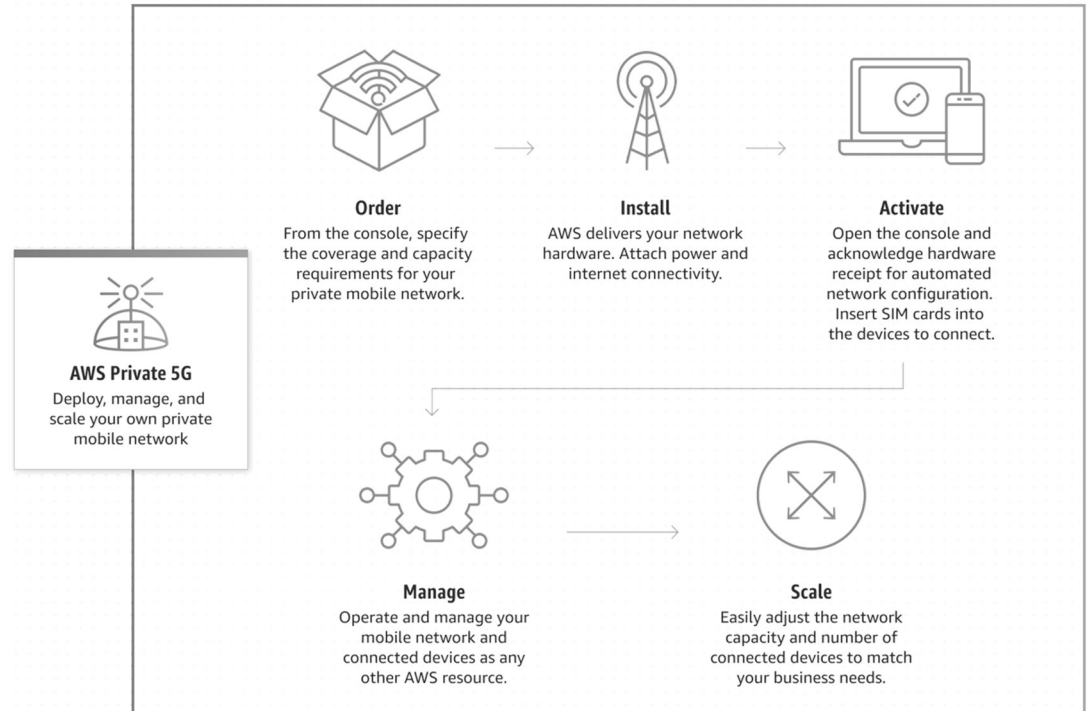


# DAY 1: 5G 네트워크 개요

## ❖ AWS Private 5G

### • 온프레미스에서 프라이빗 모바일 네트워크 배포 및 확장

1. 주문
2. 설치
3. 활성화
4. 관리
5. 확장



Source: <https://us-east-1.console.aws.amazon.com/private-networks/home?region=us-east-1#/>

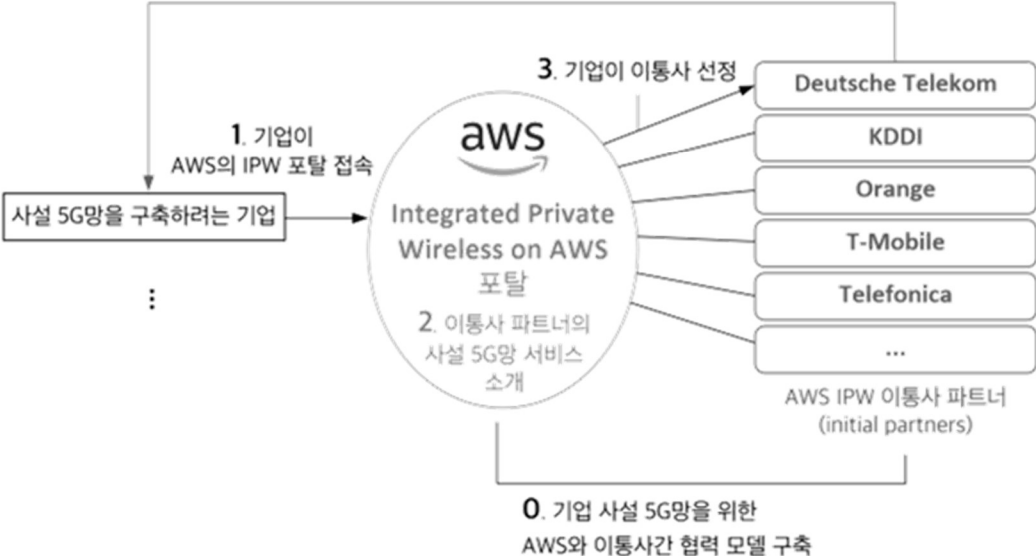


# DAY 1: 5G 네트워크 개요

## ❖ Integrated Private Wireless on AWS

- 주요 통신 서비스 공급자(CSP)가 제공하는 관리 및 검증된 사설 무선 제품을 기업에 공급
- CSP의 프라이빗 5G 및 4G LTE 무선 네트워크를 AWS 리전, AWS 로컬 영역, AWS Outposts 및 AWS Snow Family 전반에 걸친 AWS 서비스와 통합

4. 선정된 이동사가 AWS의 클라우드 인프라와 서비스를 활용해 Private 5G망 구축/운영 (매니지드 서비스 제공)



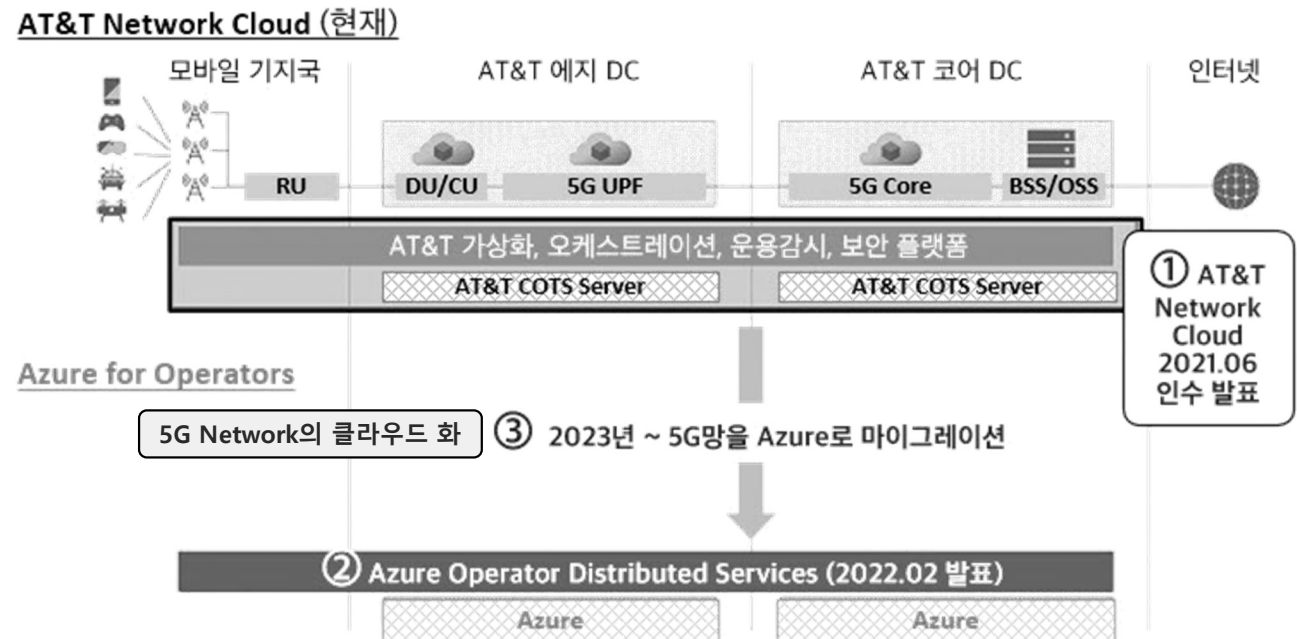
Source: <https://www.netmanias.com/ko/?m=view&id=blog&no=15663>  
 Source: <https://aws.amazon.com/telecom/integrated-private-wireless/>



# DAY 1: 5G 네트워크 개요

## ❖ Microsoft의 이통사 침투 전략 - Azure for Operators

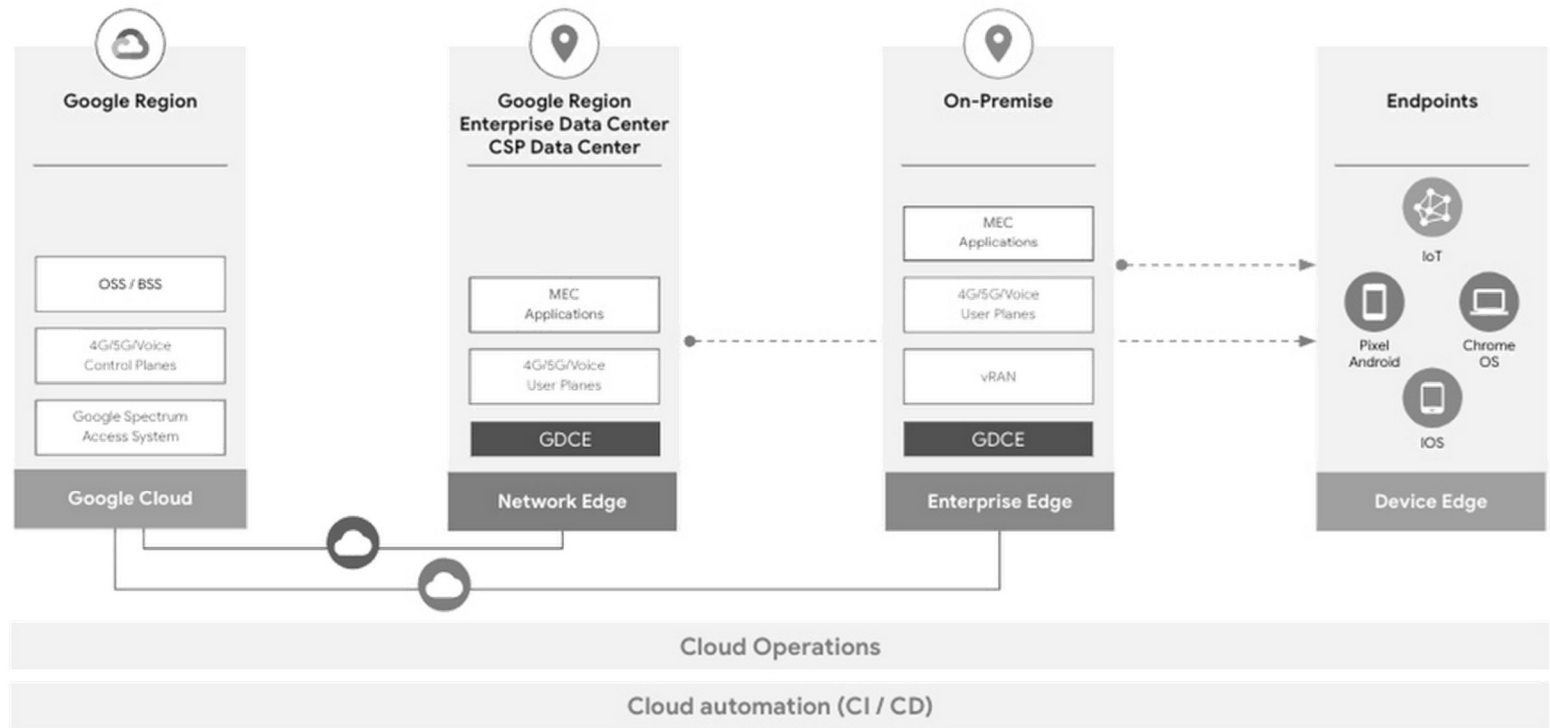
"AT&T Network Cloud" ⇨ "Azure for Operators"로의 마이그레이션



Source: <https://www.netmanias.com/ko/?m=view&id=blog&no=15484>

# DAY 1: 5G 네트워크 개요

## ❖ Google 분산 클라우드 에지의 프라이빗 네트워킹 솔루션 및 에코시스템 활용

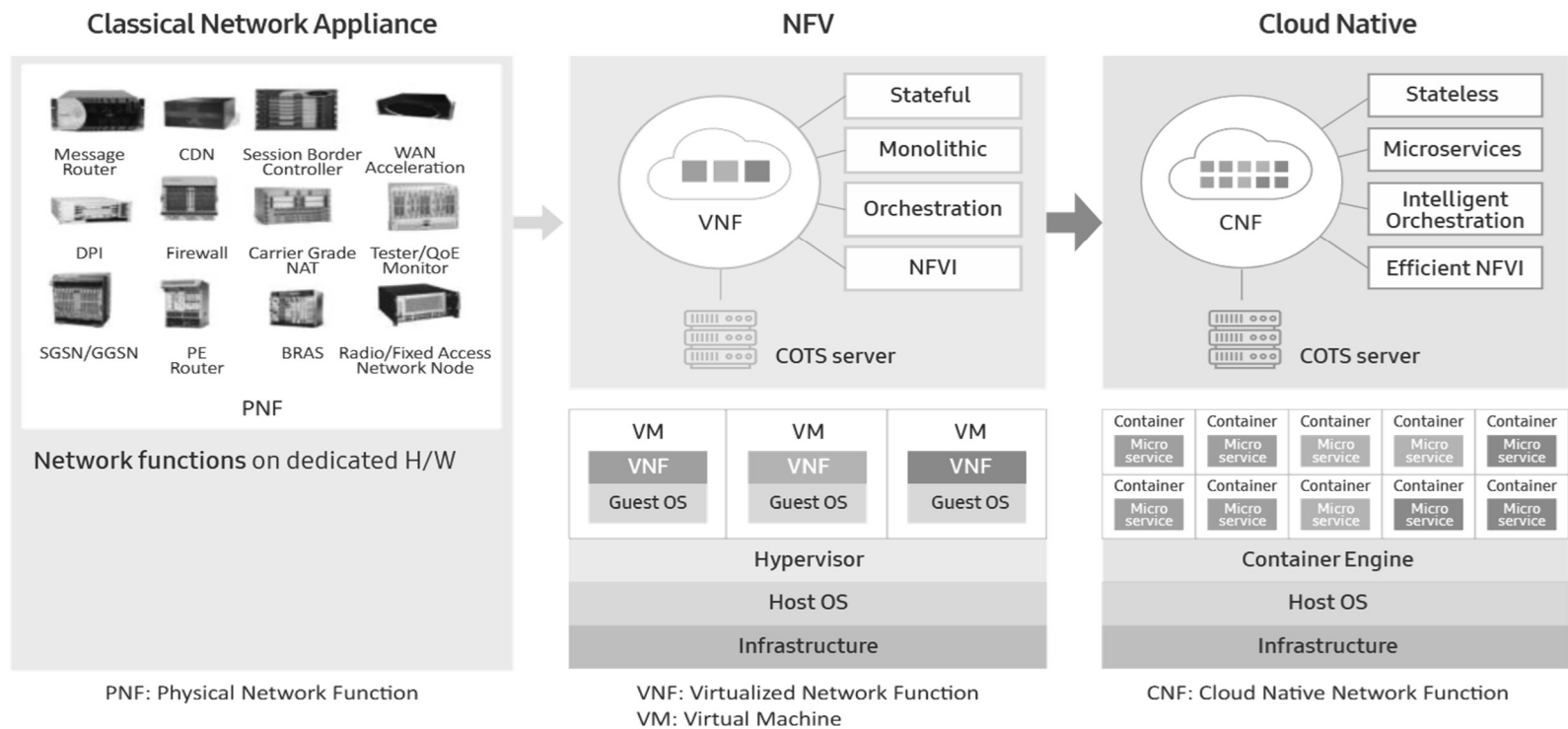


Source: <https://cloud.google.com/blog/products/networking/announcing-private-network-solutions-on-google-distributed-cloud-edge>



# DAY 1: 5G 네트워크 개요

## ❖ 전용 하드웨어에서 클라우드 네이티브 아키텍처로 진화하기

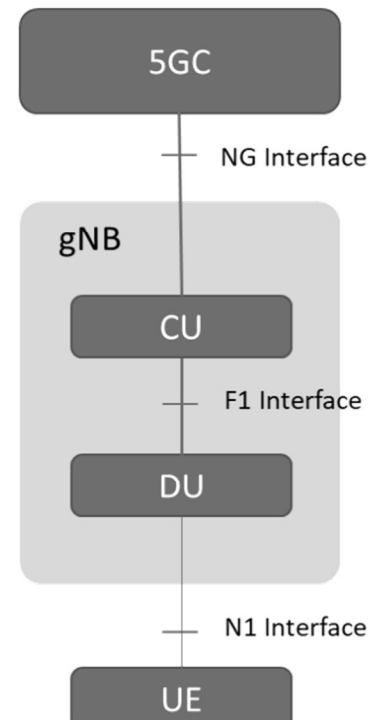
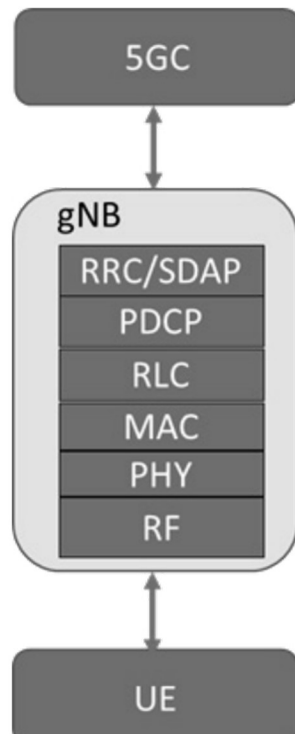


Source: <https://devopedia.org/5g-service-based-architecture#further-reading>



# DAY 1: 5G 네트워크 개요

## ❖ RAN 구조의 변화 (New C-RAN/Fronthaul)



- gNB (the NR logical node)
- Central Unit (CU)
- Distributed Unit (DU)

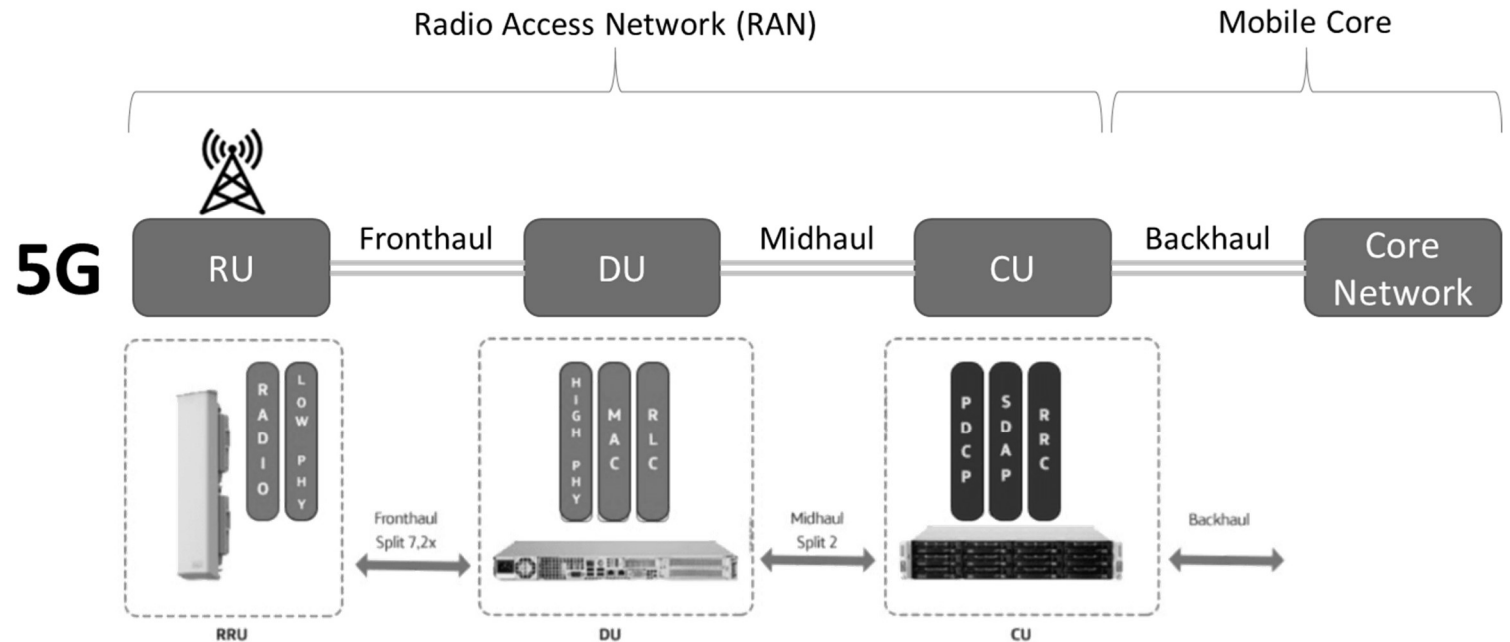




# DAY 1: 5G 네트워크 개요

## ❖ 5G RAN: RU/DU/CU

- **CU** (Centralized Unit)
- **DU** (Distributed Unit)
- **RU** (Radio Unit)



Source: <https://www.tainet.net/5g-new-business-opportunities/>

Source: <https://www.5gworldpro.com/blog/2021/02/28/o-ran-introduced-a-specific-category-of-split-7-called-split-7-2x/>

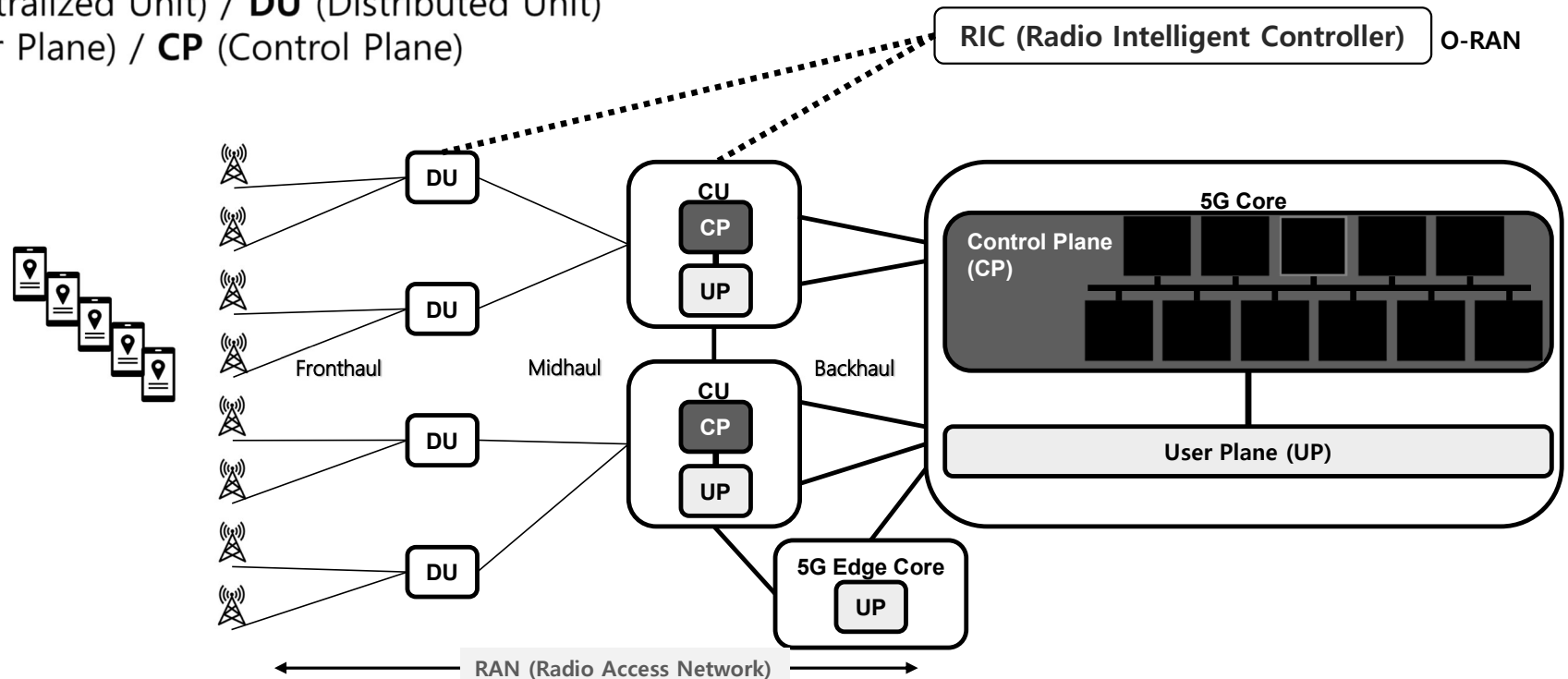


# DAY 1: 5G 네트워크 개요

## ❖ 5G Network Architecture

- **Open Systems Interconnection Layer.**

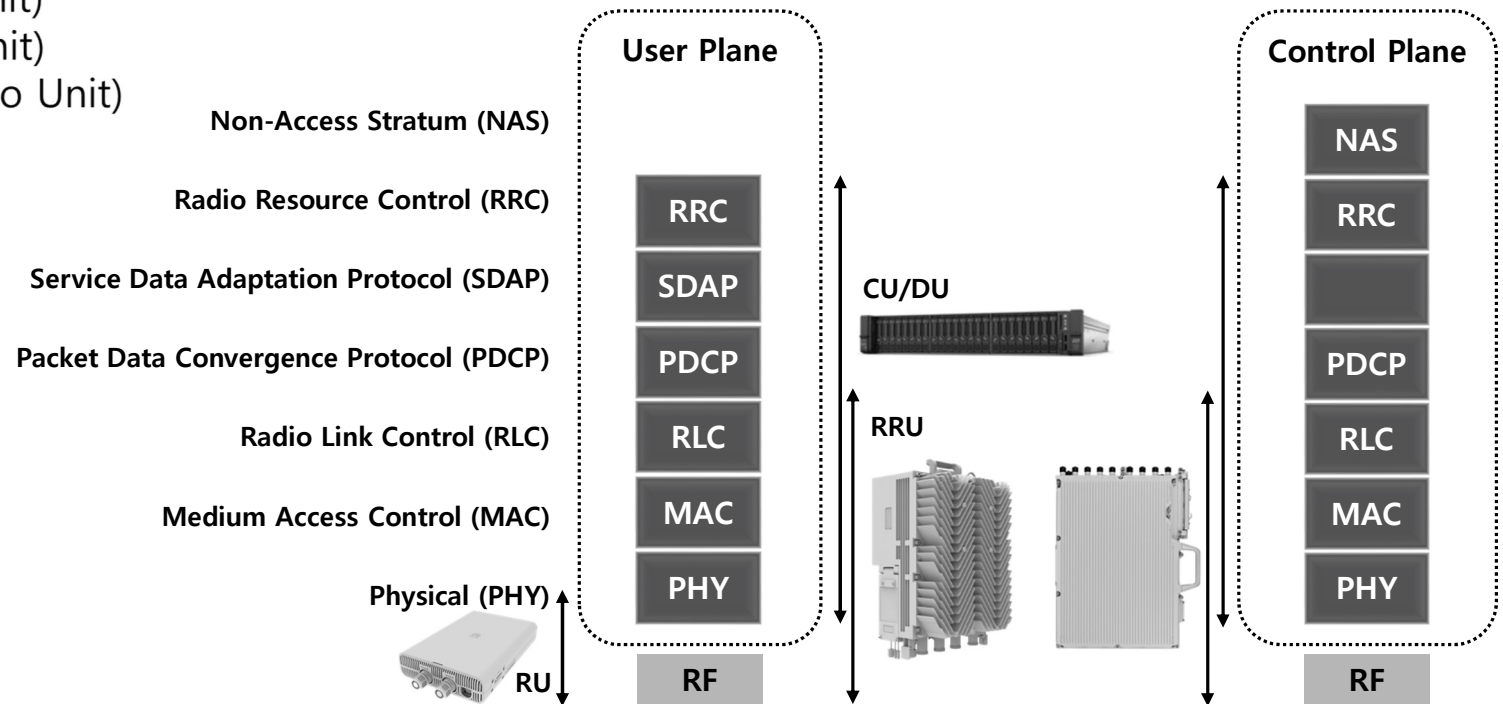
- **CU** (Centralized Unit) / **DU** (Distributed Unit)
- **UP** (User Plane) / **CP** (Control Plane)



# DAY 1: 5G 네트워크 개요

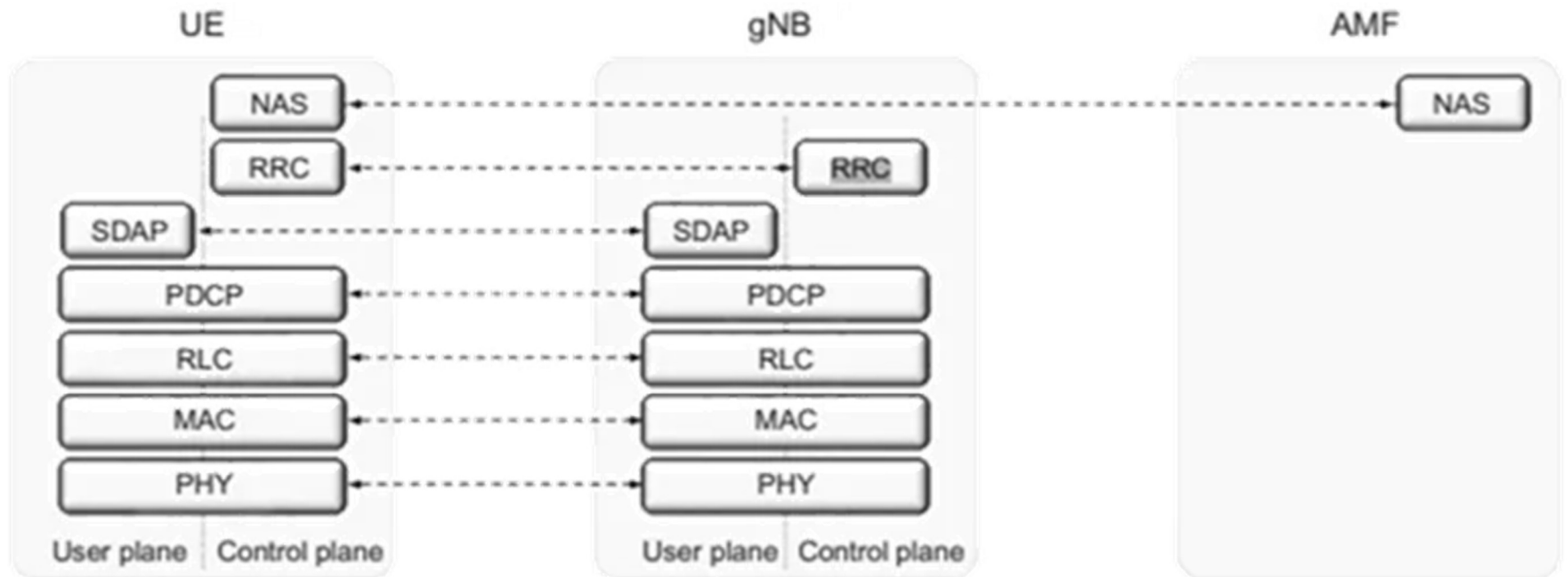
## ❖ Air Interface

- 계층 구성 (Open Systems Interconnection Layer)
  - CU (Centralized Unit)
  - DU (Distributed Unit)
  - RRU (Remote Radio Unit)
  - RU (Radio Unit)



# DAY 1: 5G 네트워크 개요

- ❖ User-plane and Control-plane protocol stack in 5G NR
  - (Ref. 5G NR by E. Dahlman et al.)



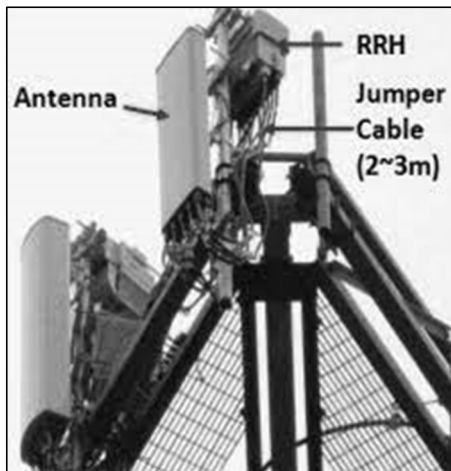
Source: <https://syedshan85.medium.com/radio-resource-control-rrc-in-5g-nr-fa0782f83977>



# DAY 1: 5G 네트워크 개요

## ❖ 5G RAN 기기

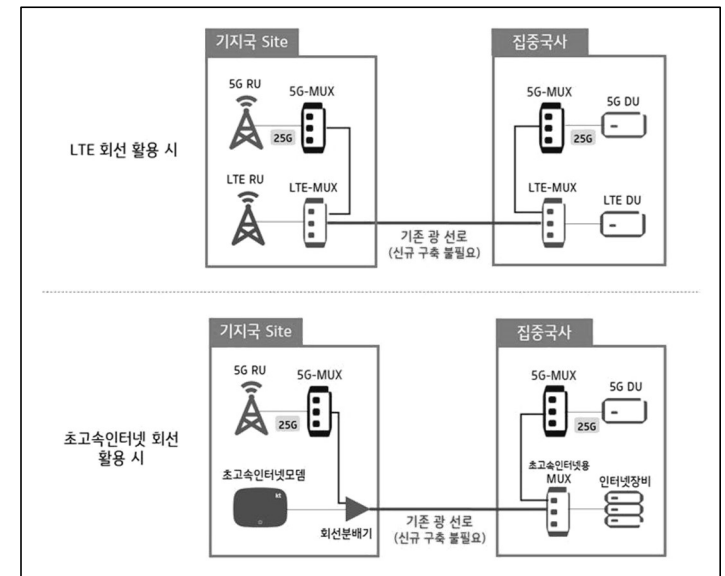
- RRH(Remote Radio Head): RU를 외장형으로 구성
- 통신부품
- MUX
- 중계기



[www.netmanias.com](http://www.netmanias.com)



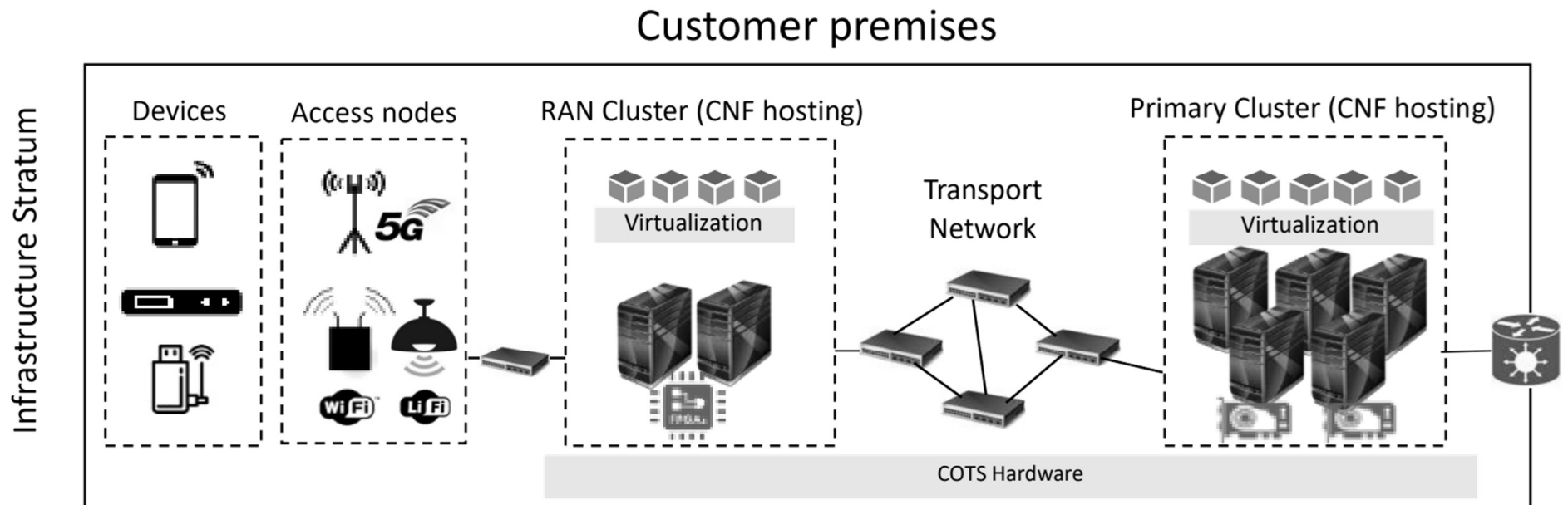
KT가 5G 네트워크 '5G MUX'와 25G 광모듈 도입 구축/시험



Source: 테크데일리(TechDaily)(<http://www.techdaily.co.kr>)

# DAY 1: 5G 네트워크 개요

## ❖ 인프라 계층 (Infrastructure stratum)

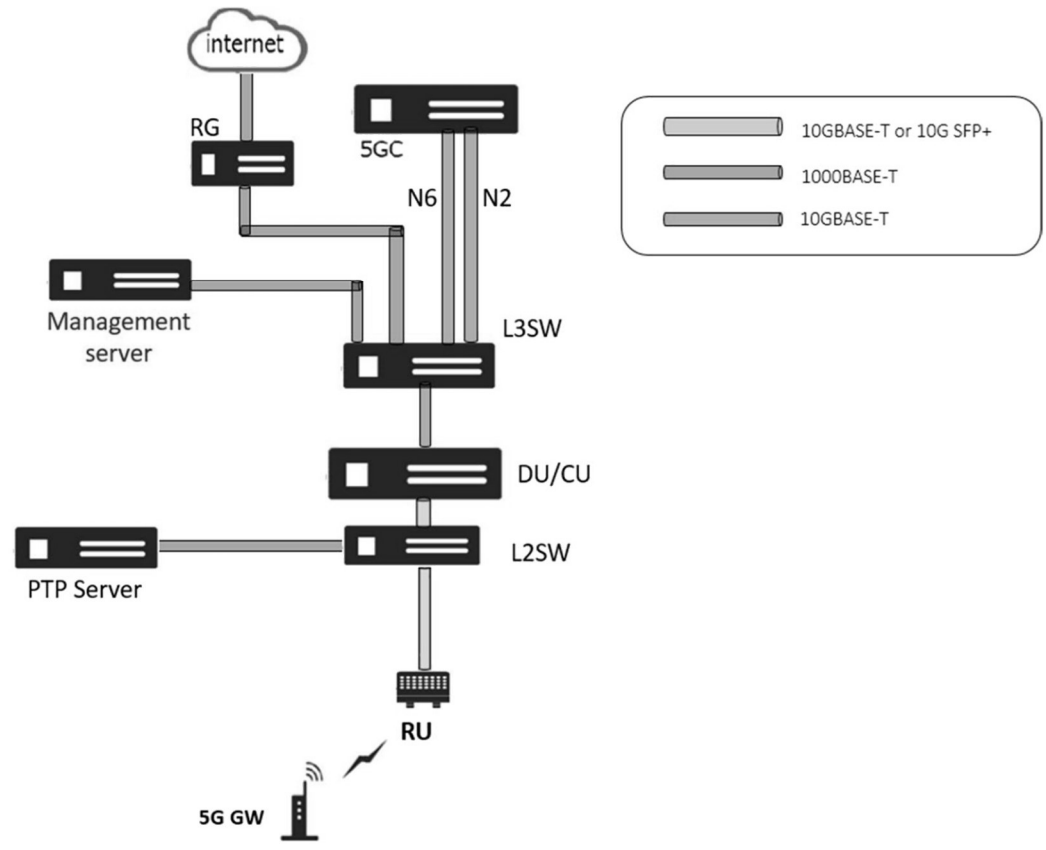


Source: 5GPPP Architecture Working Group, 5G Architecture White Paper



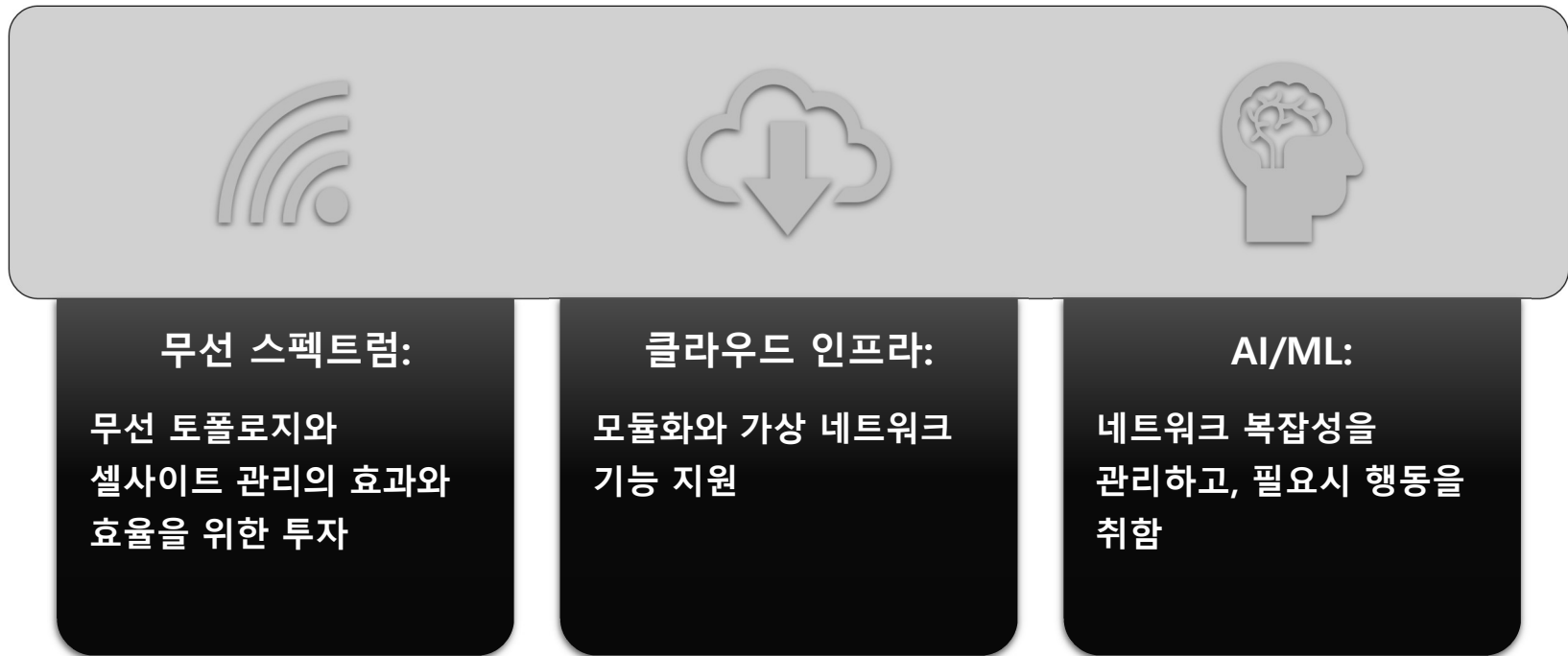
# DAY 1: 5G 네트워크 개요

## ❖ 5G end-to-end system



# DAY 1: 5G 네트워크 개요

## ❖ 5G 네트워크 설계의 발전 방향 고려

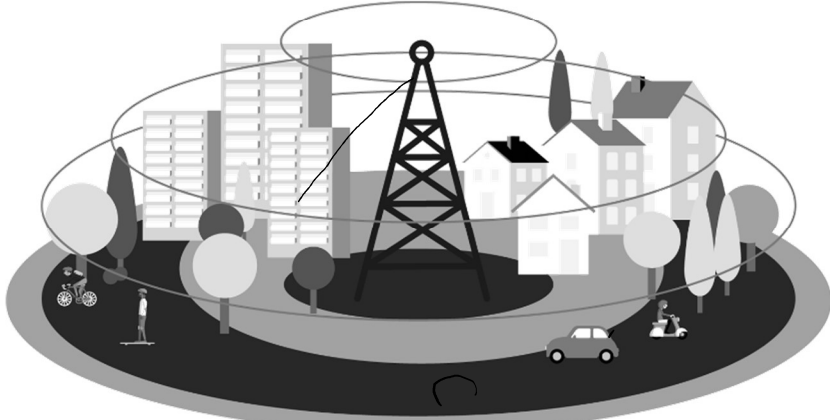




# DAY 1: 5G 네트워크 개요

- ❖ 5G는 더 큰 대역폭의 스펙트럼을 사용
- ❖ 5G 안테나는 빔포밍 기술을 이용하여 동일 주파수를 반복 사용하며 무선 대역폭을 확대

## 4G antenna



## 5G antenna



□ MIMO (Multiple Input Multiple Output) 스마트 안테나를 사용하여 빔포밍(Beamforming)을 구현

Source: <https://radio-waves.orange.com/en/radio-networks-and-antennas/5g/>



# DAY 1: 5G 네트워크 개요

## ❖ The O-RAN plugfest/PoC in East Asia

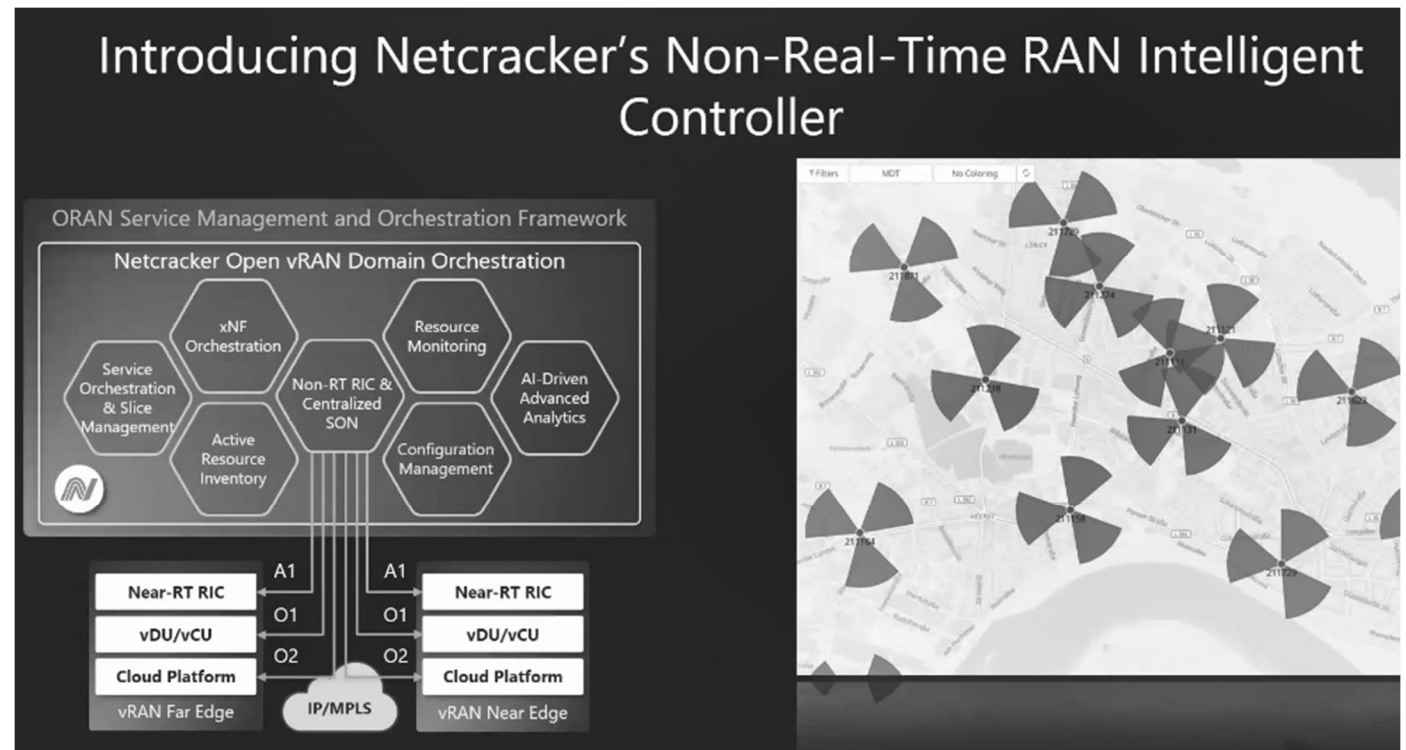


Source: <https://plugfestvirtualshowcase.o-ran.org/>



# DAY 1: 5G 네트워크 개요

## ❖ AI-Driven mMIMO Beam Optimization



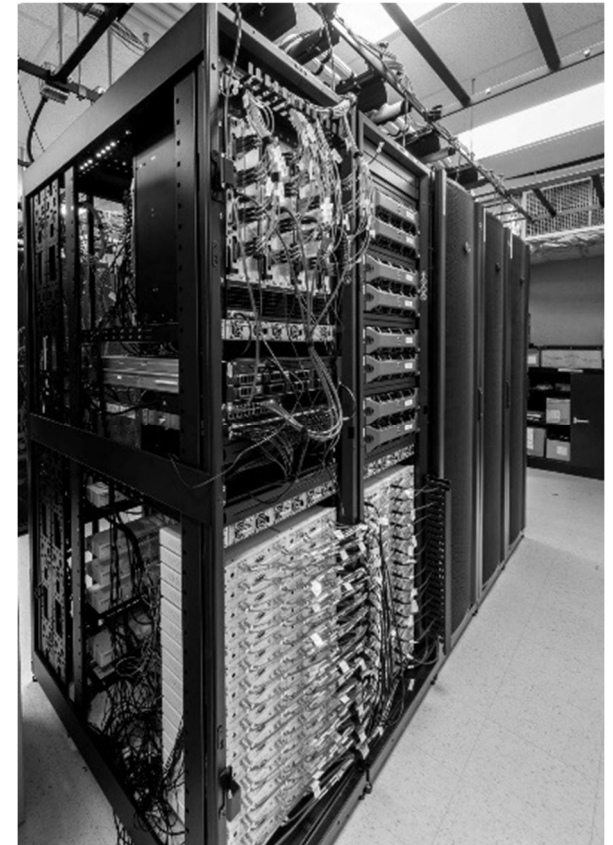
Source: <https://stage-o-ran-v2.azurewebsites.net/classic/generation/2021/category/intelligent-ran-control-demonstrations/sub/intelligent-control/110>



# DAY 1: 5G 네트워크 개요

## ❖ O-RAN 구성

- 256 software-defined radios
- 25.6 GHz of emulated bandwidth, 52 TB/s RF data
- 21 racks of radios, 171 high-performance servers w/ CPUs, GPUs
- **Massive computing capabilities (CPU, GPU, FPGA):**
  - ✓ > 900 TB of storage
  - ✓ 320 FPGAs
  - ✓ 18 10G switches
  - ✓ 19 clock distribution systems
  - ✓ 52 TB/s of digital RF data

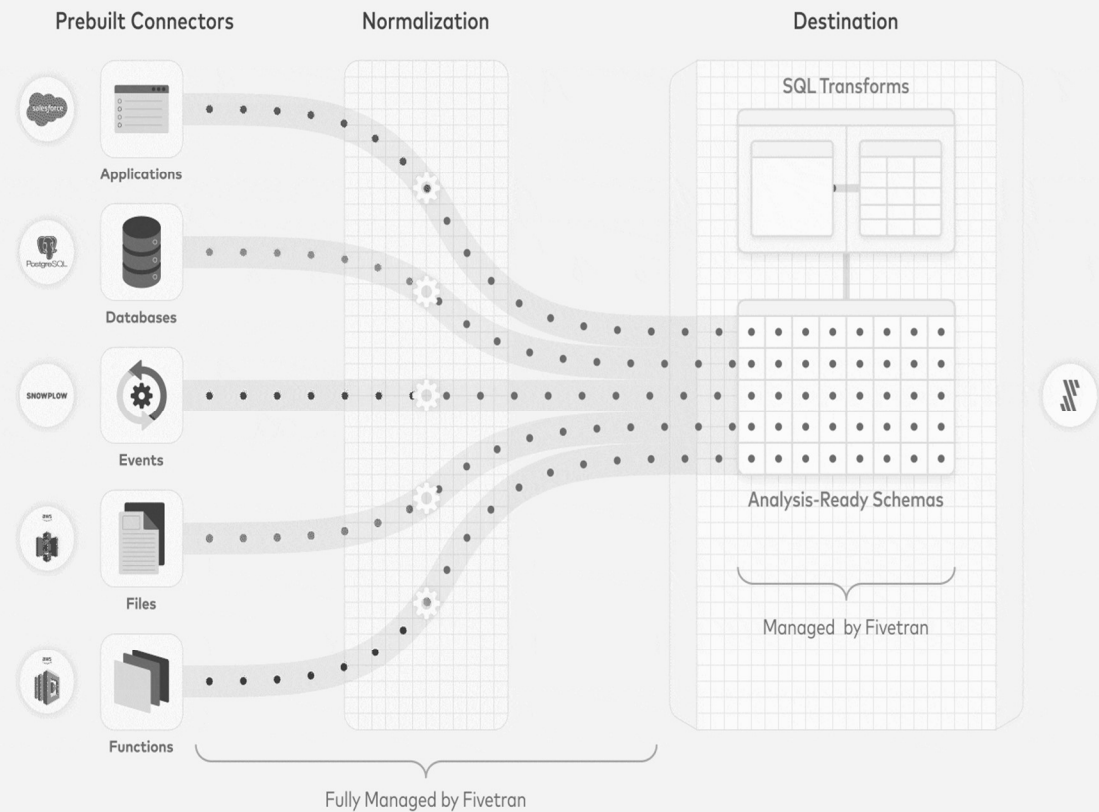


YANG models that help manage the radio units feature more than 6,000 parameters, with less than 3% of them mandatory, and network vendors also implement custom protocols.

# DAY 1: 5G 네트워크 개요

## ❖ Load data into a warehouse:

- 생성 데이터를 빠르게 분석과 선택하게 준비하는 것을 자동화 (pre-built schemas offer ready to use analytics and adapt fast to data source changes)



Source: <https://www.biztory.com/fivetran>

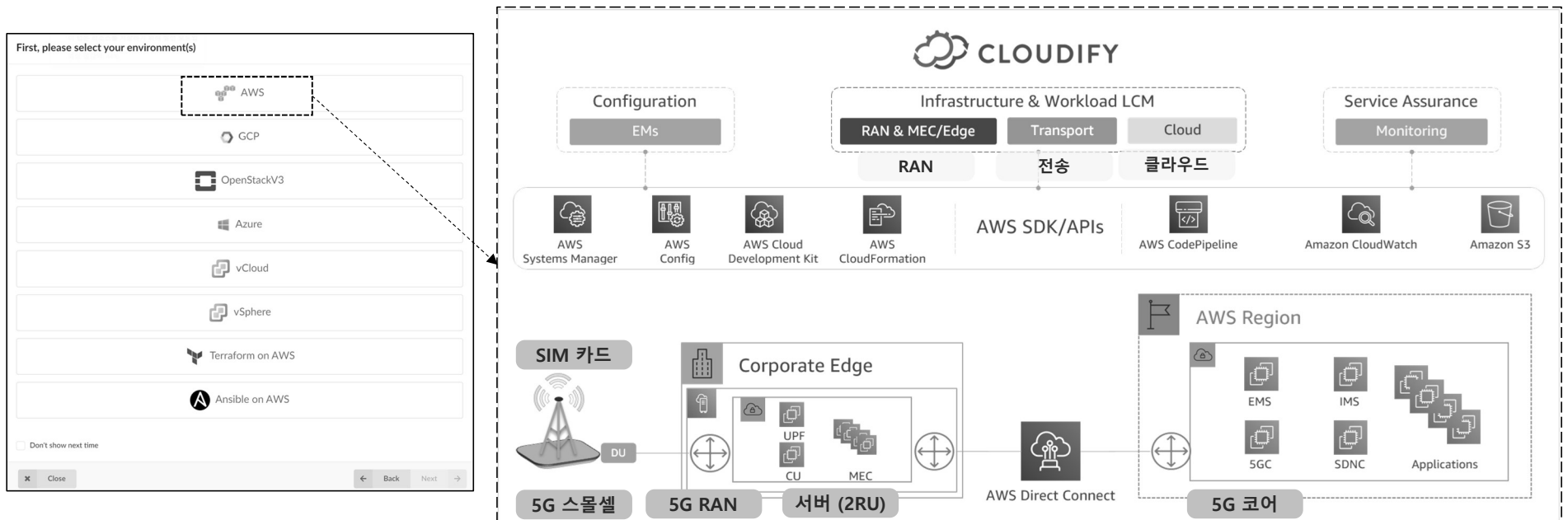




# DAY 1: 5G 네트워크 개요

## ❖ Cloudfify: AWS 서비스에 5G 네트워크 슬라이싱 적용

- 멀티클라우드 오케스트레이션: Cloudfify is for multi-cloud orchestration
- 아마존 AWS 적용 (예): Cloudfify architecture on AWS.



Source: <https://aws.amazon.com/blogs/industries/implementing-5g-network-slicing-with-cloudfify-on-aws/>

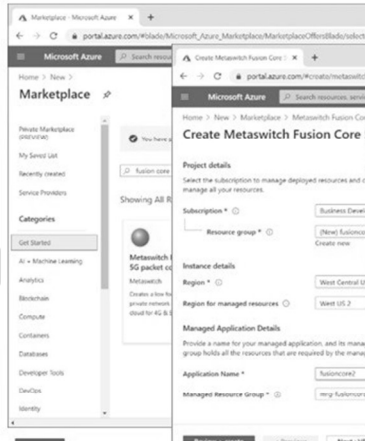
# DAY 1: 5G 네트워크 개요

## ❖ Fusion Core - 5G Packet Core @ Azure Marketplace

### Azure Marketplace Deployment

Azure 마켓플레이스에서 5G 코어 다운로드 적용

1. 주문

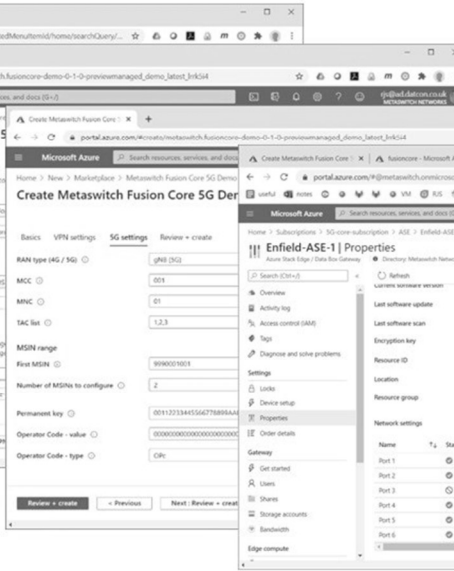


Step 1  
Go to Marketplace to order 5G Edge components

Step 2  
Configure cloud resources and assign to 5G Core

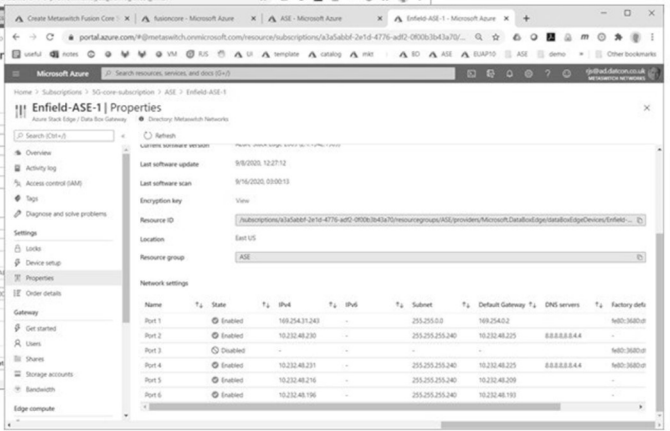
Metaswitch Networks

2. 코어 구성



3. 기기 구성  
Step 3  
Configure 5G Network parameters, devices

4. 5G 에지  
Step 4  
5G Edge ready for RAN



Source: [https://azuremarketplace.microsoft.com/ko-kr/marketplace/apps/metaswitch.fusioncore\\_0-1-0?tab=Overview](https://azuremarketplace.microsoft.com/ko-kr/marketplace/apps/metaswitch.fusioncore_0-1-0?tab=Overview)





# DAY 1: 5G 네트워크 개요

- ❖ **Microsoft claims it's making progress assembling a more expansive telco cloud stack for operators six months after it inhaled AT&T's Network Cloud technology via acquisition.**
  - **Azure for Operators, now combined with the crown jewels of AT&T's seven-year effort in SDN and network virtualization, includes more than 60 cloud-native network functions (CNF) and virtual network functions (VNF) from 15 vendors, Microsoft's VP of 5G strategy Shawn Haki explained in a blog post.**
  - **AT&T in selling its technology to Microsoft also announced plans to move its 5G network core, workloads, and services to Microsoft's Azure for Operators platform.**

통신사(AT&T)에서 클라우드 서비스 마켓 상의 VNF/CNF 판매

**Matt Kapko** | Senior Editor, January 7, 2022 8:00 PM

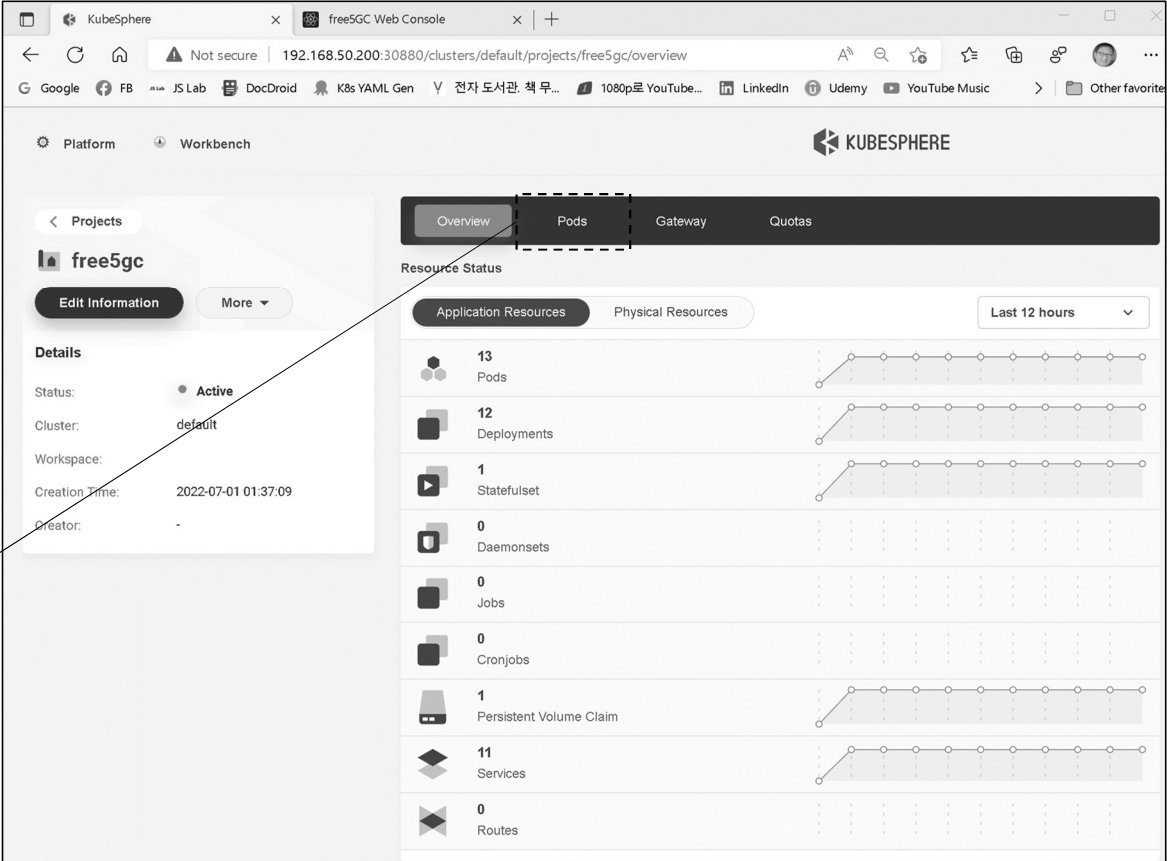
Source: <https://www.sdxcentral.com/articles/news/microsoft-teases-5g-cloud-core-progress-post-att-deal/2022/01/>



# DAY 1: 5G 네트워크 개요

## ❖ 오픈소스 5G Core/RAN/UE (예)

- Cloud Native (K8s)
- Project (free5gc)
- Pods (CPU/Memory/...)



Overview | **Pods** | Gateway | Quotas

Pods

Search by name

Name	Node	Pod IP address	CPU	Memory
ueransim-v1-ue-784f76f55-kd...	192.168.5... Node	10.233.95.107	CPU 1 m	Memory 7.96 Mi
ueransim-v1-gnb-6fd9c7f79c-...	192.168.5... Node	10.233.95.106...	CPU 0 m	Memory 5.96 Mi
mongodb-0	192.168.5... Node	10.233.95.78	CPU 14 m	Memory 208.59 Mi
free5gc-v1-free5gc-webui-we...	192.168.5... Node	10.233.95.77	CPU 1 m	Memory 9.96 Mi
free5gc-v1-free5gc-upf-upf-7...	192.168.5... Node	10.233.95.83...	CPU 0 m	Memory 65.13 Mi
free5gc-v1-free5gc-udr-udr-5...	192.168.5... Node	10.233.95.79	CPU 0 m	Memory 9.12 Mi

Total: 13



# DAY 1: 5G 네트워크 개요

## ❖ Quectel 5G @ MS Azure

- Quectel RM500-GL 5G 모뎀을 사용하여 5G 또는 LTE를 통해 Azure Percept DK 연결

클라우드 서비스사의 개발 키트 연결 5G 모뎀



Source: <https://docs.microsoft.com/ko-kr/azure/azure-percept/connect-over-cellular-usb-quectel>



# DAY 1: 5G 네트워크 개요

## ❖ gNodeB

- 지노드비, next generation Node B, gNodeB, gNB
- 3GPP에서 사용하는 공식 명칭이다. 3GPP에서 5G NR(New Radio) 기지국을 '다음 세대(next generation)'의 알파벳 'g'를 인용하여 gNodeB로 정하였다.
- 5G 무선 접속망 NG-RAN(Next Generation-Radio Access Network)은 다수의 gNodeB들로 연결 구성되며, 기존의 eNodeB도 포함될 수 있다.

시스템	3G	LTE, 4G	5G
전체 이동 통신 시스템	UMTS	EPS	5GS
무선 접속 기술	UTRA	E-UTRA	NR 또는 E-UTRA
무선 접속망	UTRAN	E-UTRAN	NG-RAN
기지국	Node B	eNodeB	gNodeB

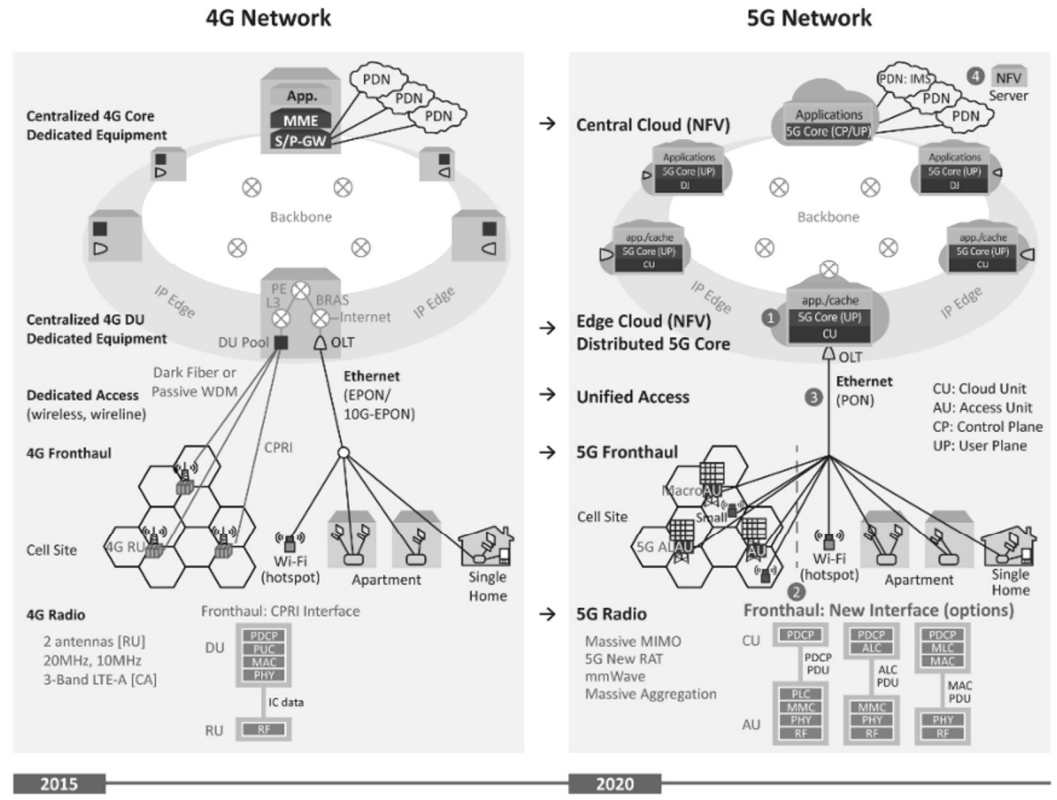
Source: [http://terms.tta.or.kr/dictionary/dictionaryView.do?word\\_seq=167786-3](http://terms.tta.or.kr/dictionary/dictionaryView.do?word_seq=167786-3)



# DAY 1: 5G 네트워크 개요

## ❖ From 4G to 5G

가상화와 이더넷 기술기반 유선망 확대



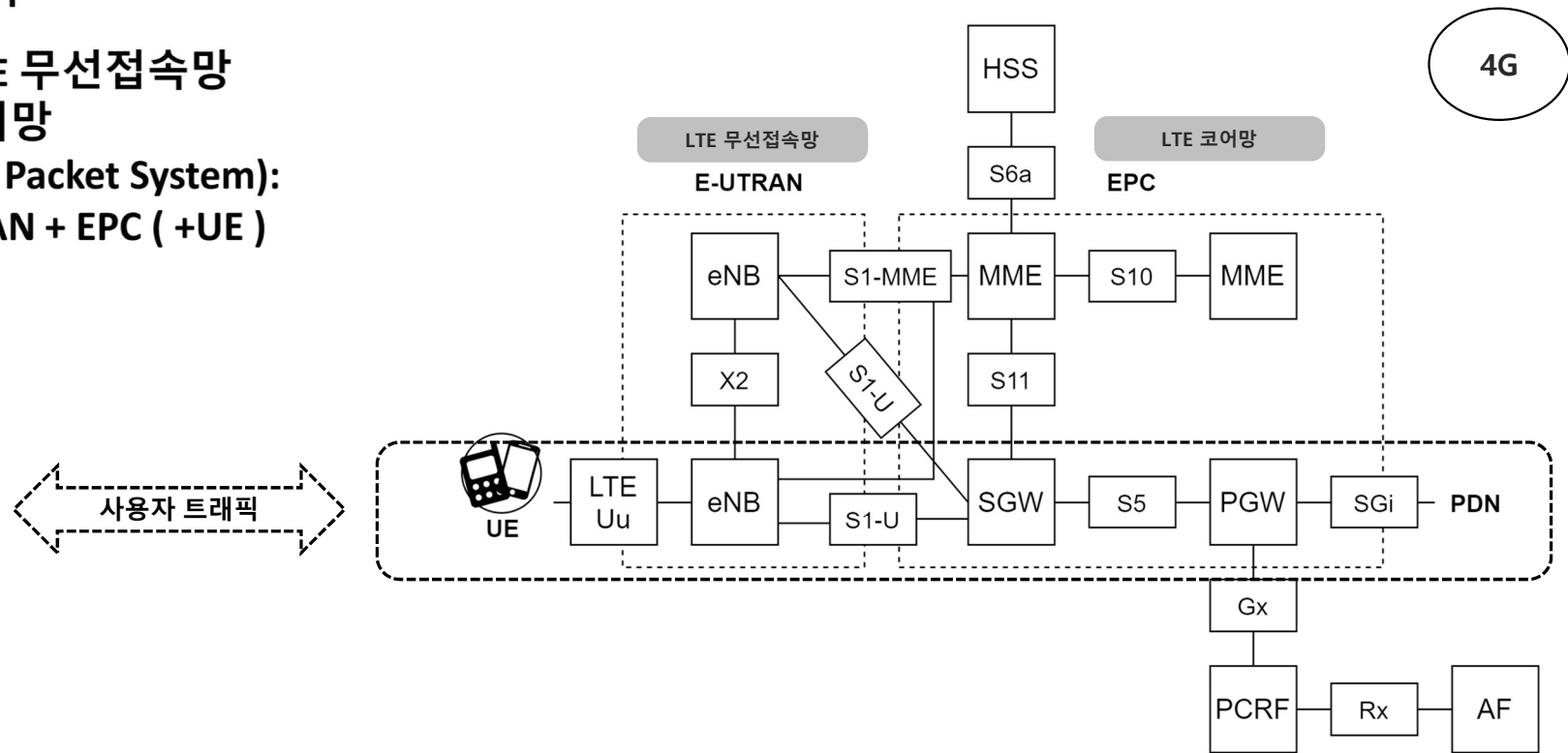
Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020



# DAY 1: 5G 네트워크 개요

## ❖ LTE 아키텍처

- E-UTRAN: LTE 무선접속망
- EPC: LTE 코어망
- EPS (Evolved Packet System):
- EPS = E-UTRAN + EPC ( +UE )

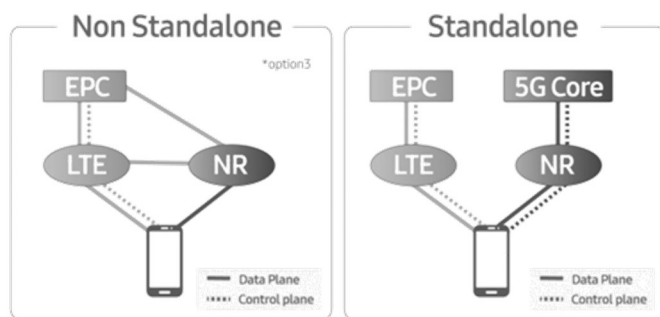
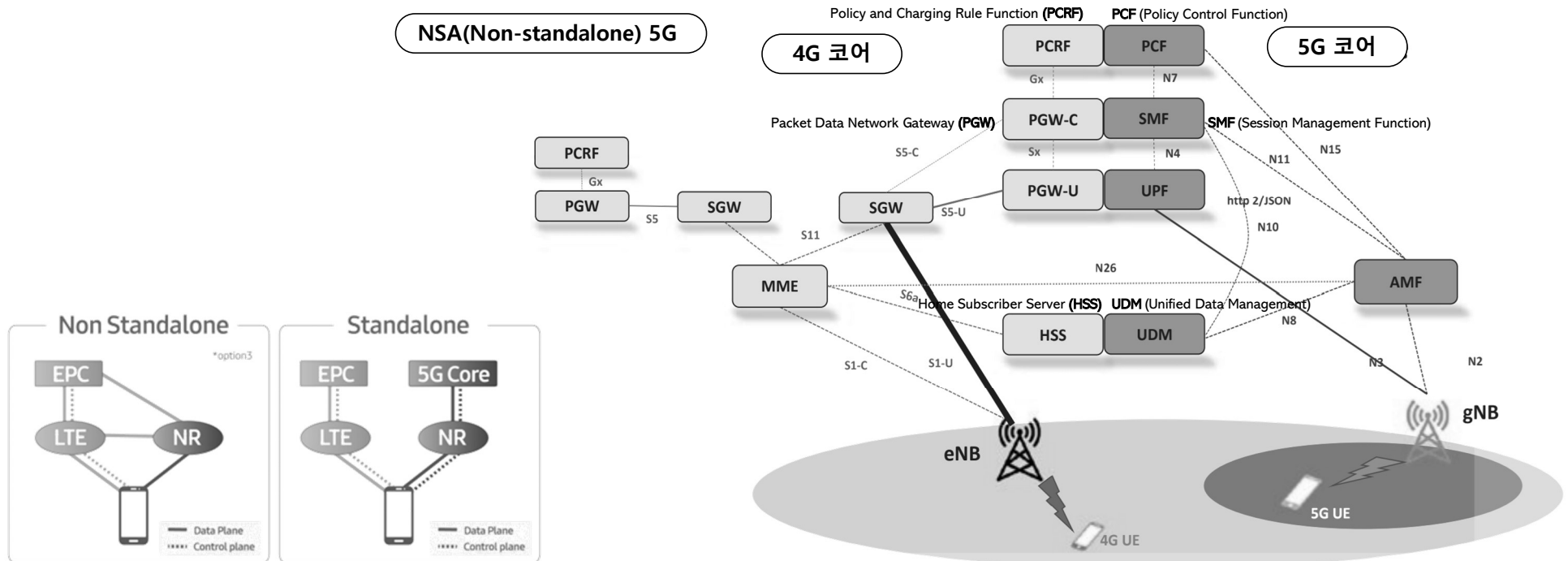


4G



# DAY 1: 5G 네트워크 개요

- ❖ NSA(Non-standalone) 5G: 4G LTE architecture with a 5G RAN.
- ❖ SA(Standalone) 5G: 5G RAN and a cloud-native 5G core.

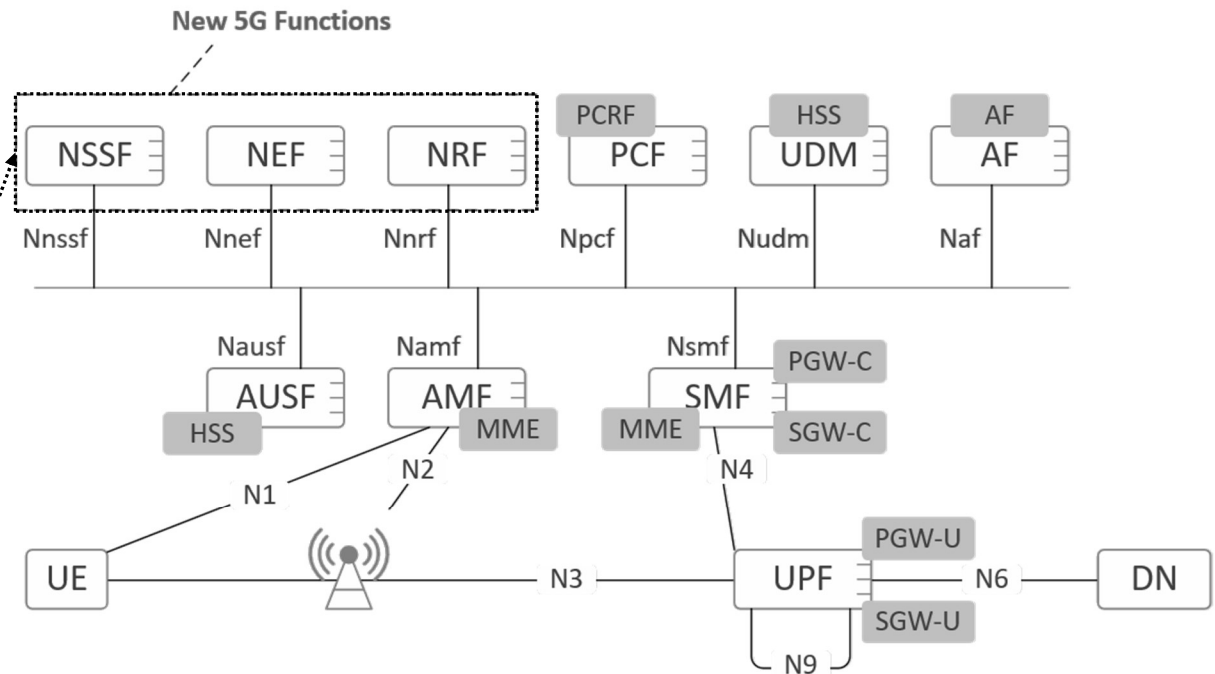


# DAY 1: 5G 네트워크 개요

## ❖ 4G EPC functions mapped to 5G core network functions

### • Main functions in 5G SBA

- AUSF Authentication Server Function
- AMF Access and Mobility Management Function
- AF Application Function
- DN Data Networks
- SMF Session Management Function
- NEF Network Exposure Function
- NSSF Network Slice Selection Function
- NRF Network Repository Function
- PCF Policy Control Function
- UPF User PLane Function
- (R)AN (Radio) Access Network



Source: Mastering Service Mesh, Anjali Khatri, Vikram Khatri, 2020 Packt Publishing





# DAY 1: 5G 네트워크 개요

## ❖ 5G Core NF (Network Function)

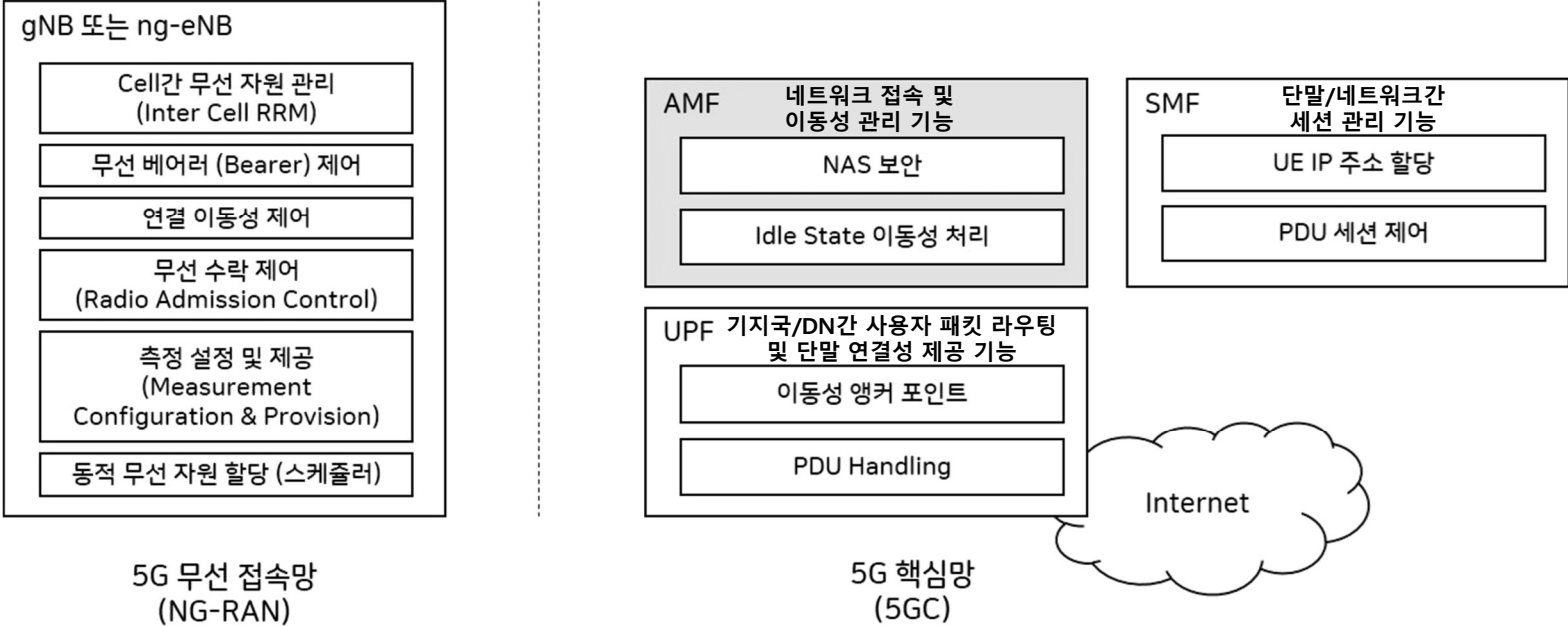
<b>UPF(User Plane Function)</b>	기지국/DN간 사용자 패킷 라우팅 및 단말 연결성 제공 솔루션
<b>AMF(Access and Mobility Management Function)</b>	네트워크 접속 및 이동성 관리 솔루션
<b>SMF(Session Management Function)</b>	단말/네트워크간 세션 관리 솔루션
<b>PCF(Policy Control Function)</b>	데이터 패킷 플로우 정책 제어 솔루션
<b>UDM(Unified Data Management)</b>	사용자 정보 및 정책 관리 솔루션
<b>UDR(Unified Data Repository)</b>	사용자 정보 및 정책 통합 저장 솔루션
<b>AUSF(Authentication Server Function)</b>	네트워크/사용자 상호 인증정보 관리 솔루션
<b>CBCF(Cell Broadcast Centre Function)</b>	재난문자 전송 솔루션
<b>CHF(Charging Function)</b>	온라인/오프라인 통합 실시간 과금 솔루션
<b>NEF(Network Exposure Function)</b>	네트워크 기능 개방 솔루션
<b>NRF(NF Repository Function)</b>	5G 망 내 NF 연동 제어 솔루션
<b>NSSF(Network Slice Selection Function)</b>	네트워크 슬라이싱 제어 솔루션
<b>SEPP(Security Edge Protection Proxy)</b>	망 간 로밍 게이트웨이
<b>SMSF(SMS Function)</b>	메시지(SMS) 서비스 인증 및 중계 솔루션

Source: <http://www.uangel.com/kr/index.php/products/5g/5g-core/>



# DAY 1: 5G 네트워크 개요

- ❖ AMF: 접속과 이동성 관리 기능, 接續-移動性管理技能, Access and Mobility Management Function
- ❖ SMF: 세션 관리 기능, -管理技能, Session Management Function



Source: [http://terms.tta.or.kr/dictionary/dictionaryView.do?word\\_seq=170480-7](http://terms.tta.or.kr/dictionary/dictionaryView.do?word_seq=170480-7)

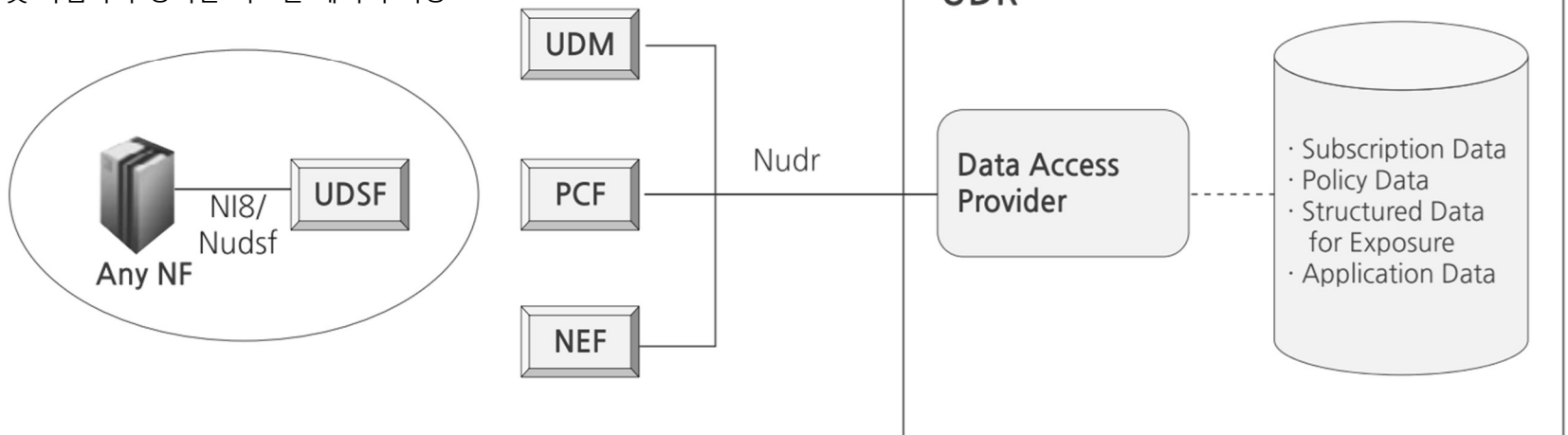


# DAY 1: 5G 네트워크 개요

## ❖ UDR

- UDR (Unified Data Repository)
- 5G 비상태 네트워크 기능 및 데이터 저장 구조

- UDM (Unified Data Management): 통합 데이터 관리
- PCF(Policy Control Function): 정책 제어 기능
- NEF (Network Exposure function): 네트워크 노출 기능
- UDSF (Unstructured Data Storage Function): 제조사 및 사업자가 정의한 비표준 데이터 저장소



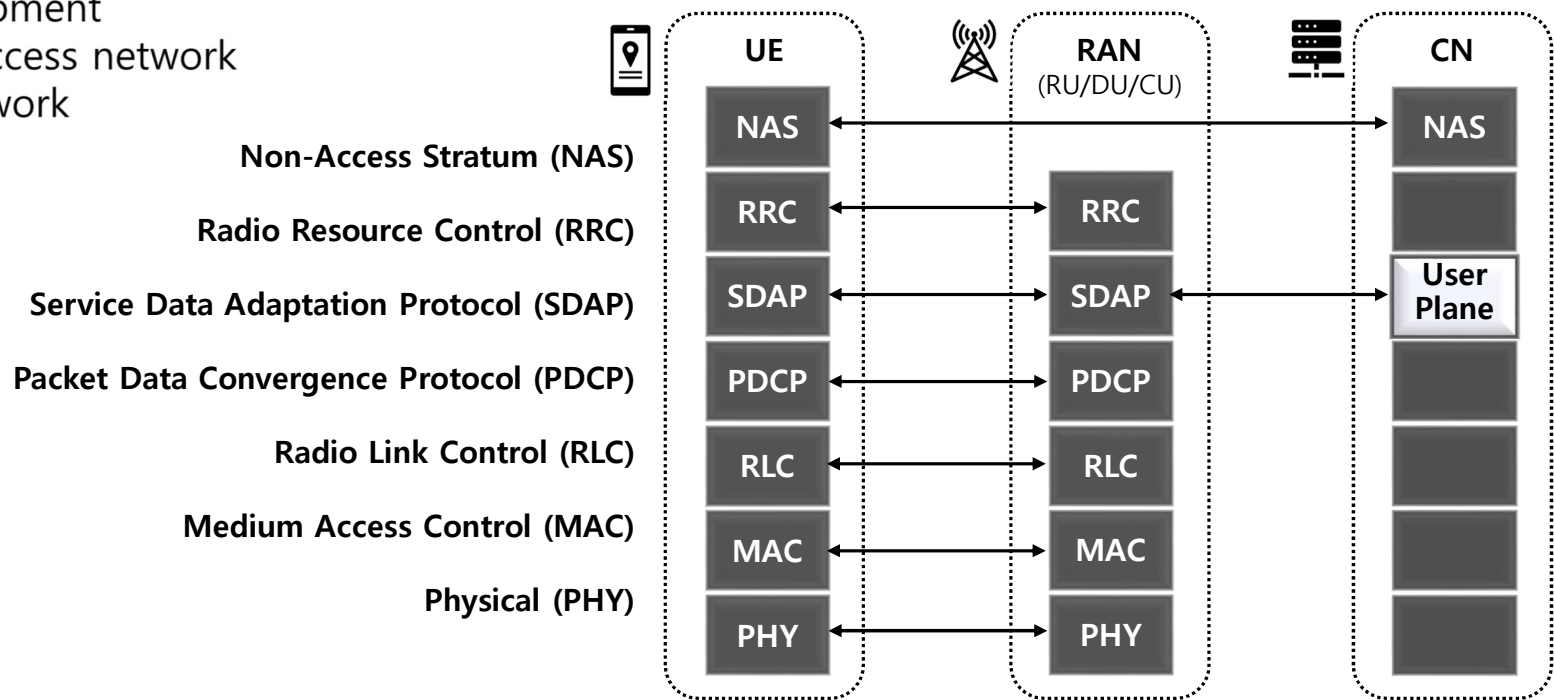
Source: <https://www.tta.or.kr/data/androReport/ttaJnal/175-2-3-4.pdf>



# DAY 1: 5G 네트워크 개요

## ❖ Air Interface

- 계층 구성 (Open Systems Interconnection Layer)
  - UE: User Equipment
  - RAN: Radio access network
  - CN: Core Network

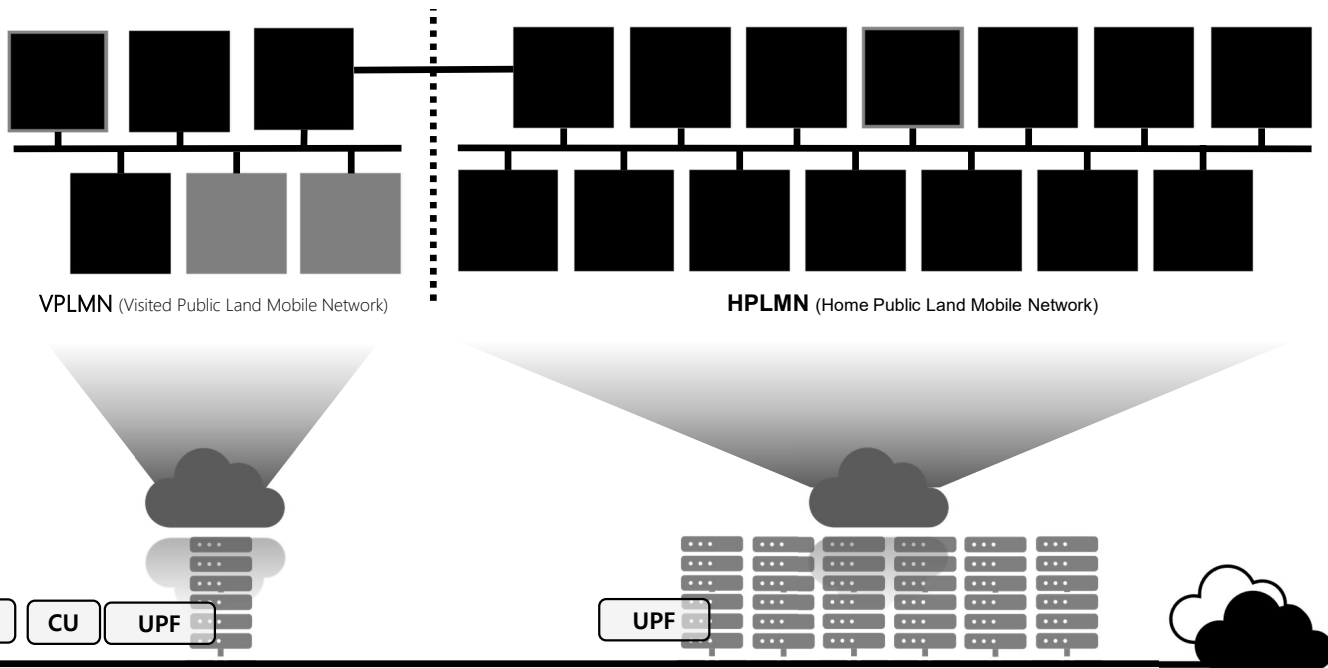


# DAY 1: 5G 네트워크 개요

## ❖ 5G Core의 클라우드화

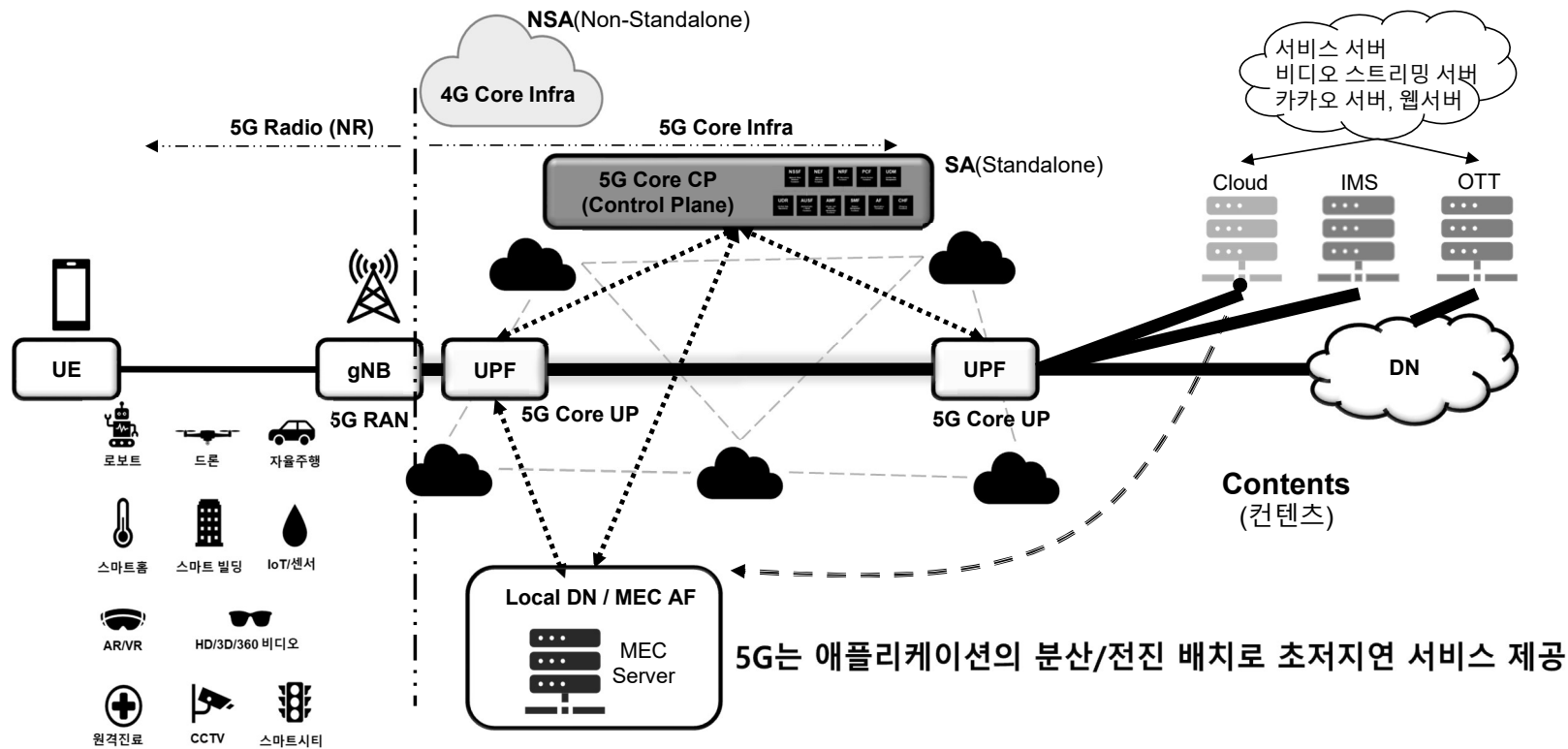
### • 5G Core와 RAN

5G Core NF (Network Function)	
CBCF (Cell Broadcast Centre Function)	재난문자 전송 솔루션
CHF (Charging Function)	온라인/오프라인 통합 실시간 과금 솔루션
NEF (Network Exposure Function)	네트워크 기능 개방 솔루션
NRF (NF Repository Function)	5G 망 내 NF 연동 제어 솔루션
NSSF (Network Slice Selection Function)	네트워크 슬라이싱 제어 솔루션
SEPP (Security Edge Protection Proxy)	망 간 로밍 게이트웨이
SMSF (SMS Function)	메시지(SMS) 서비스 인증 및 중계 솔루션



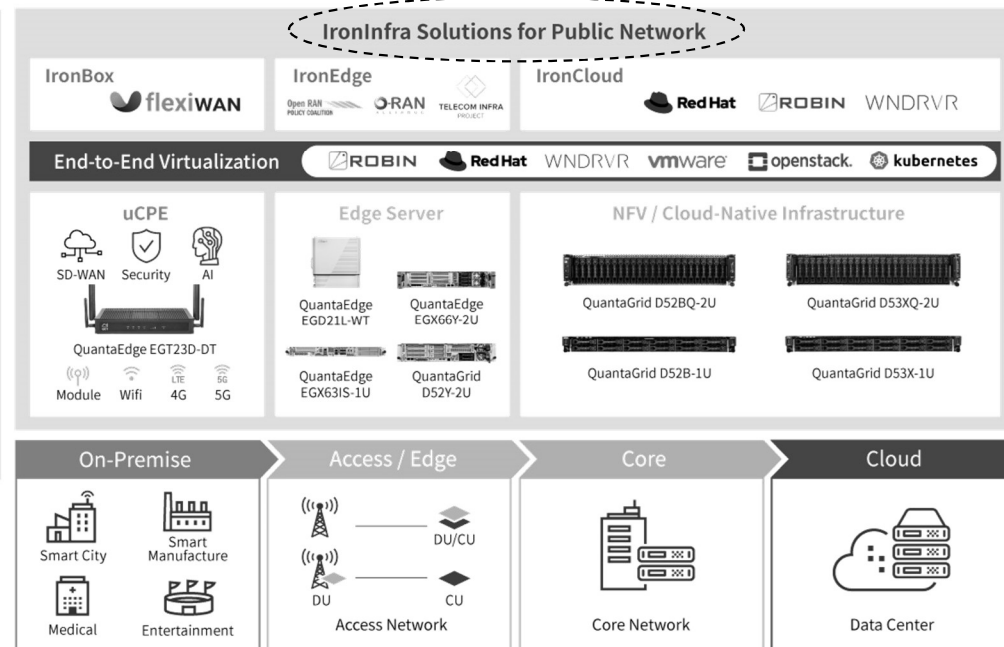
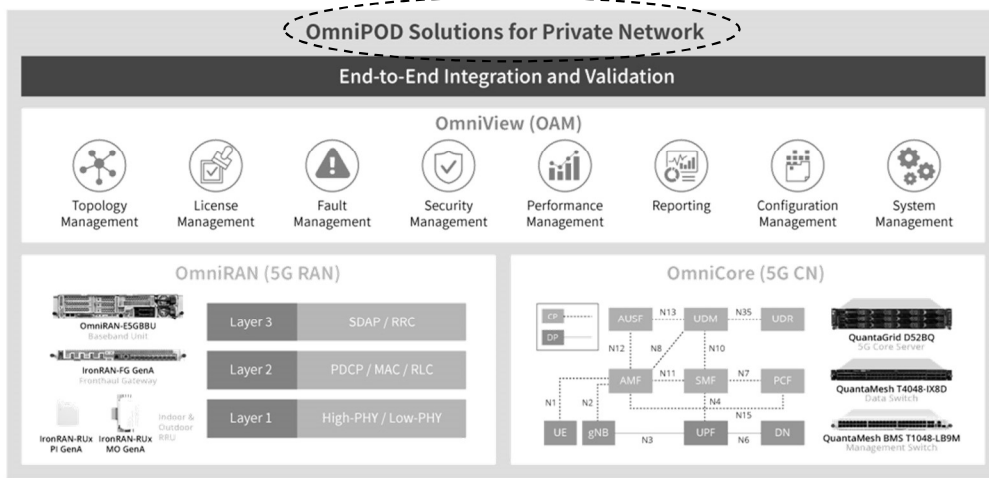
# DAY 1: 5G 네트워크 개요

## ❖ 에지의 분산 클라우드 (Distributed cloud with autonomous edge)



# DAY 1: 5G 네트워크 개요

## ❖ 제조사 (예): QCT

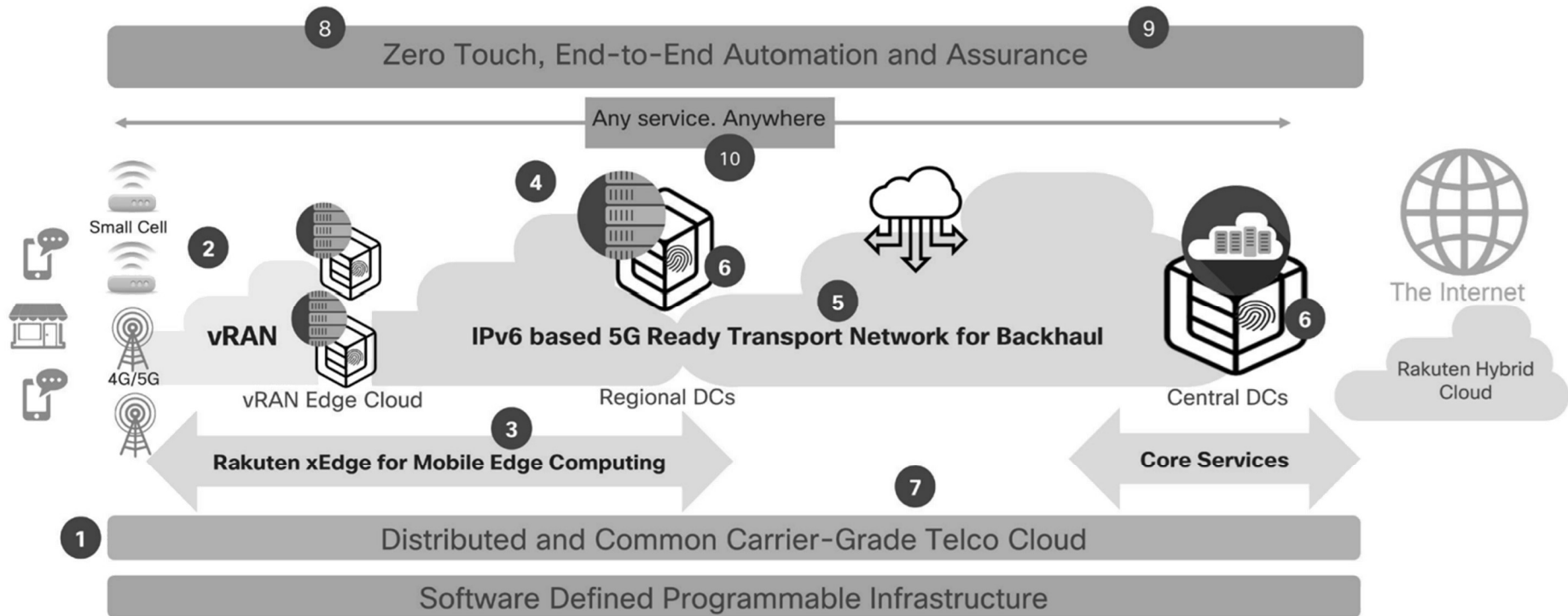


Source: <https://go.qct.io/telco/>



# DAY 1: 5G 네트워크 개요

❖ 제조사의 분산 Telco Cloud 기반 가상화 아키텍처 (예): 시스코, Rakuten



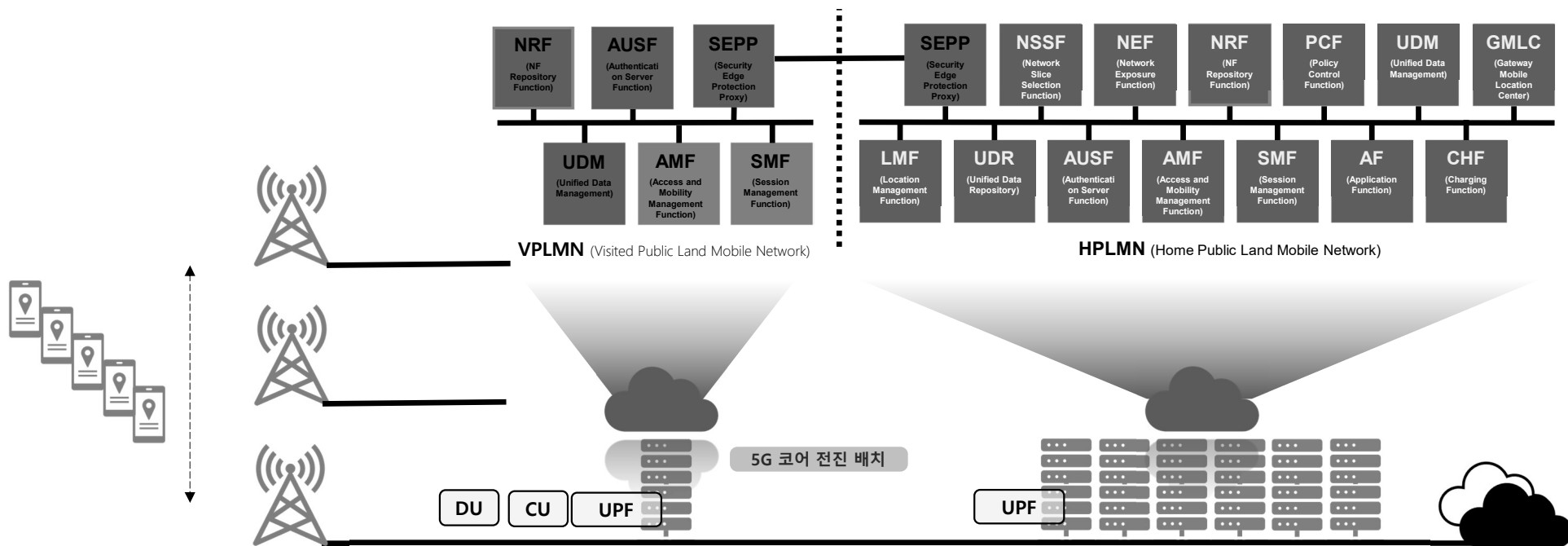
Source: <https://www.cisco.com/c/dam/en/us/products/collateral/cloud-systems-management/elastic-services-controller-esc/reimagining-mobile-network-white-paper.pdf>





# DAY 1: 5G 네트워크 개요

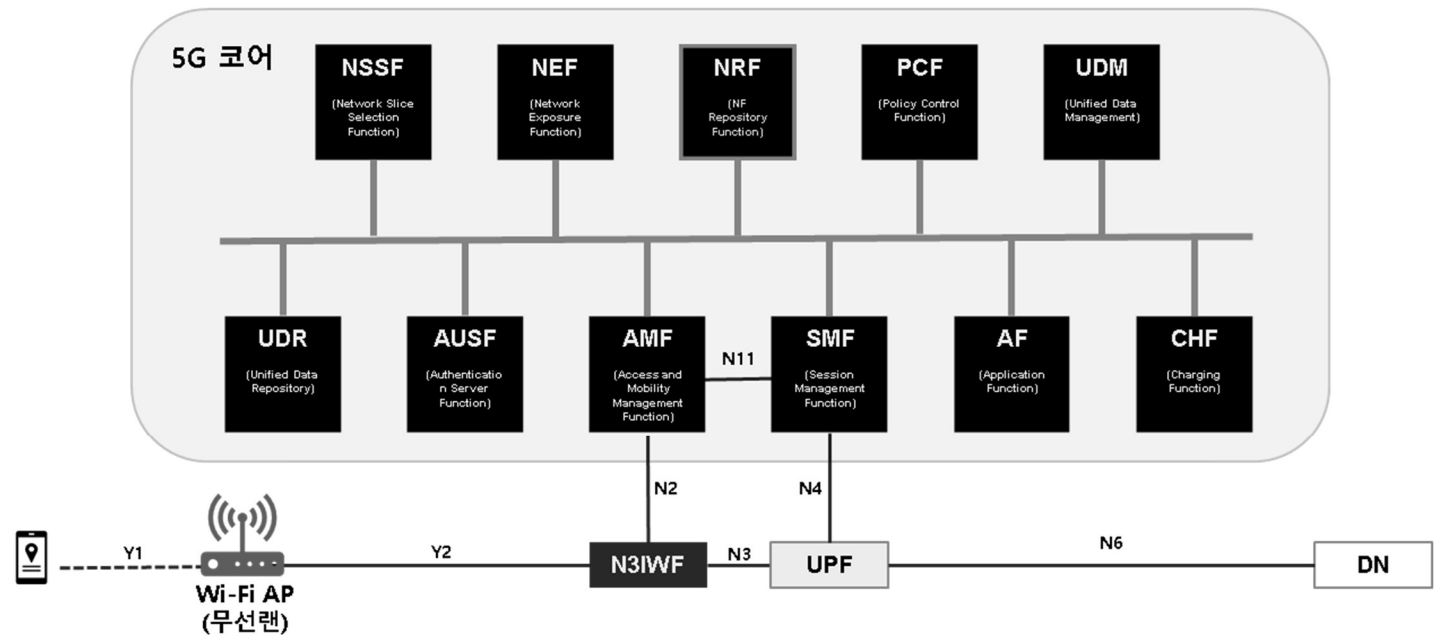
## ❖ 5G 코어 기능의 분산 배포



# DAY 1: 5G 네트워크 개요

## ❖ non-3GPP

- Architecture of untrusted non-3GPP access using Wi-Fi network
- N3IWF: Non-3GPP Interworking Function

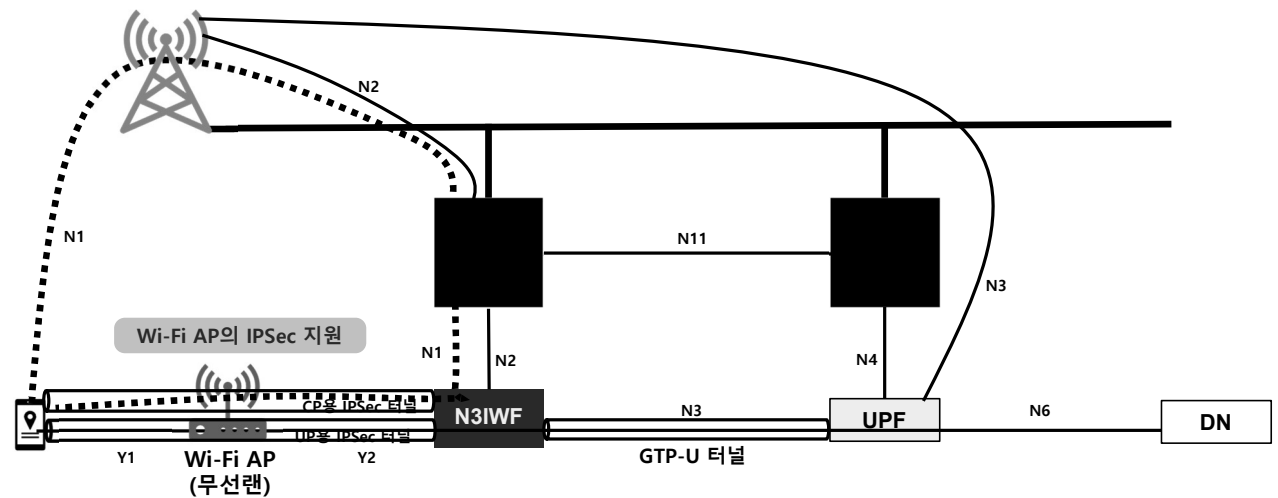
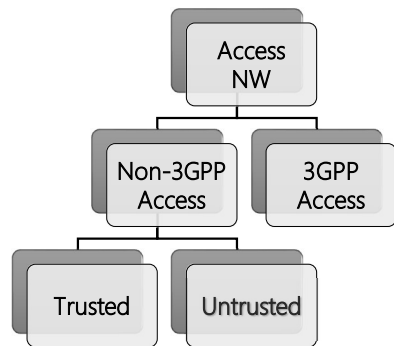


# DAY 1: 5G 네트워크 개요

## ❖ non-3GPP

### • Architecture of untrusted non-3GPP access using Wi-Fi network

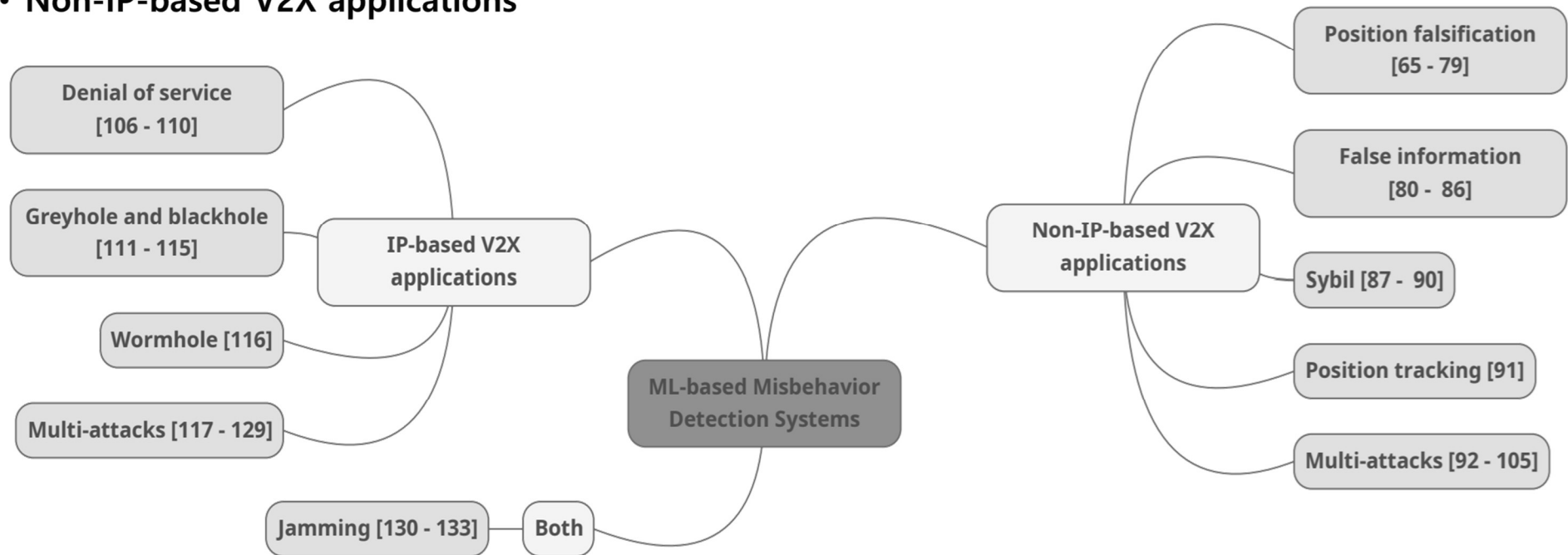
- CP용 IPsec 터널, UP용 IPsec 터널, GTP-U 터널



# DAY 1: 5G 네트워크 개요

## ❖ Taxonomy of ML-based Misbehavior Detection Systems

- IP-based V2X applications
- Non-IP-based V2X applications

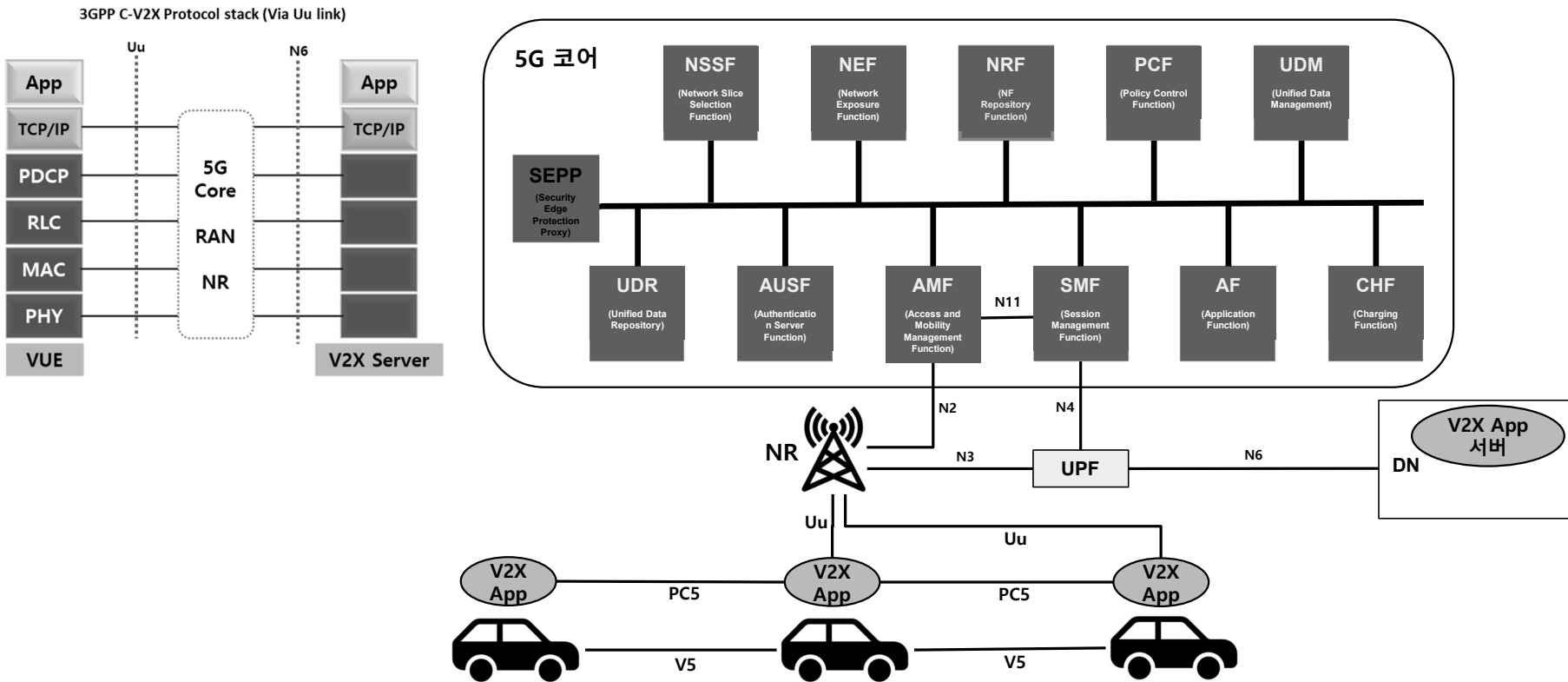


Source: A Survey on Machine Learning-base Misbehavior Detection Systems for 5G and Beyond Vehicular Network, Abdelwahab Boualouache, Member, IEEE and Thomas Engel, Member, IEEE



# DAY 1: 5G 네트워크 개요

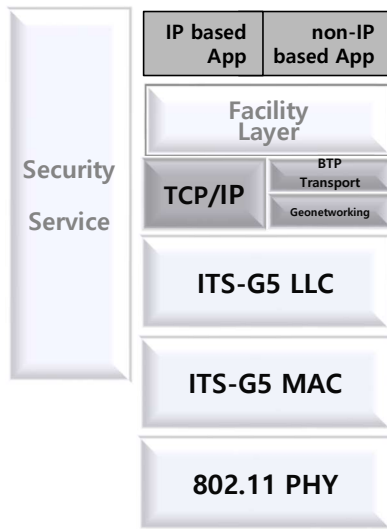
## ❖ 5G-V2X Architecture



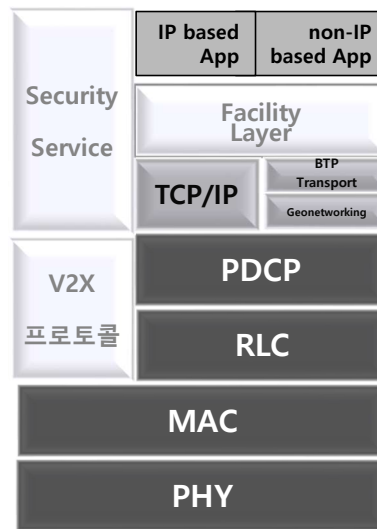
# DAY 1: 5G 네트워크 개요

## ❖ V2X Protocol Stacks

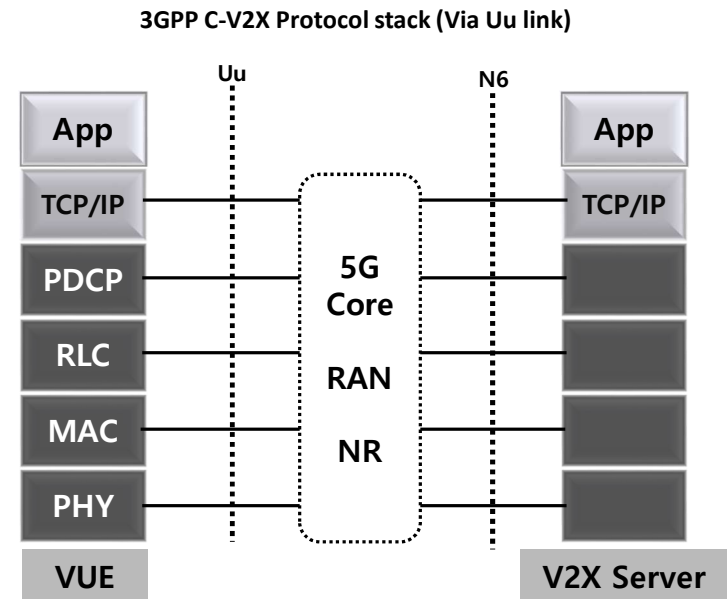
- ETSI ITS-G5 Protocol stack
- 3GPP C-V2X Protocol stack
- 3GPP C-V2X Protocol stack (Via Uu link)



ETSI ITS-G5 Protocol stack



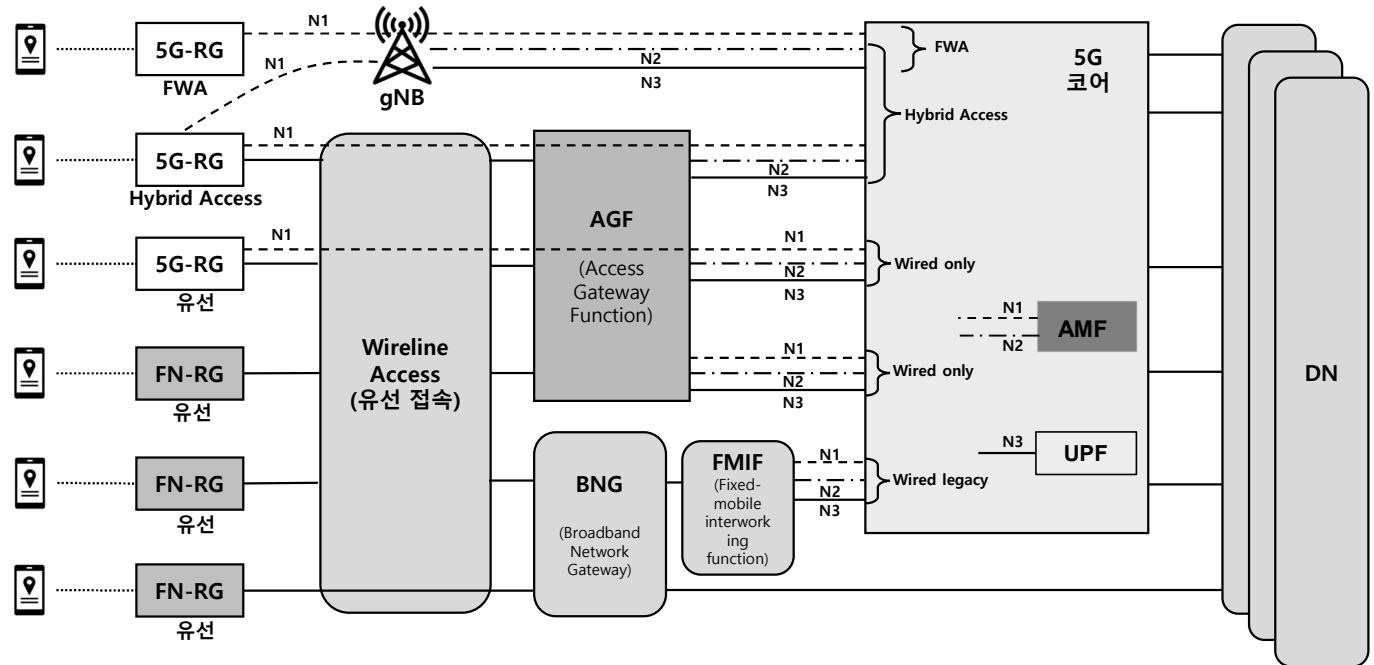
3GPP C-V2X Protocol stack



# DAY 1: 5G 네트워크 개요

## ❖ FMC(Fixed Mobile Convergence)

- 5G RG (Residential Gateway)
- FN RG (Fixed Network Residential Gateway)



# DAY 1: 5G 네트워크 개요

## ❖ non-3GPP Access Network 비교

- COMPARISON BETWEEN NON-3GPP ACCESS NETWORKS ACCORDING TO 3GPP (REL-15/REL-16)

Access network type	Traditional end-device	Residential gateway	Type of communication	Main NF	UE 5G capable/NAS signaling support	Roaming support
Untrusted	UE non-3GPP	Access point	Unsecure	N3IWF	Yes	LBO & HR
Trusted	UE non-3GPP	TNAP	Secure	TNGF	Yes	LBO & HR
Trusted	N5CW	TWAP	Secure	TWIF	No	LBO
Wireline	UE non-3GPP	5G-RG	Secure	W-AGF	Yes	-
Wireline	N5GC	FN-RG	Secure	W-AGF	No	-

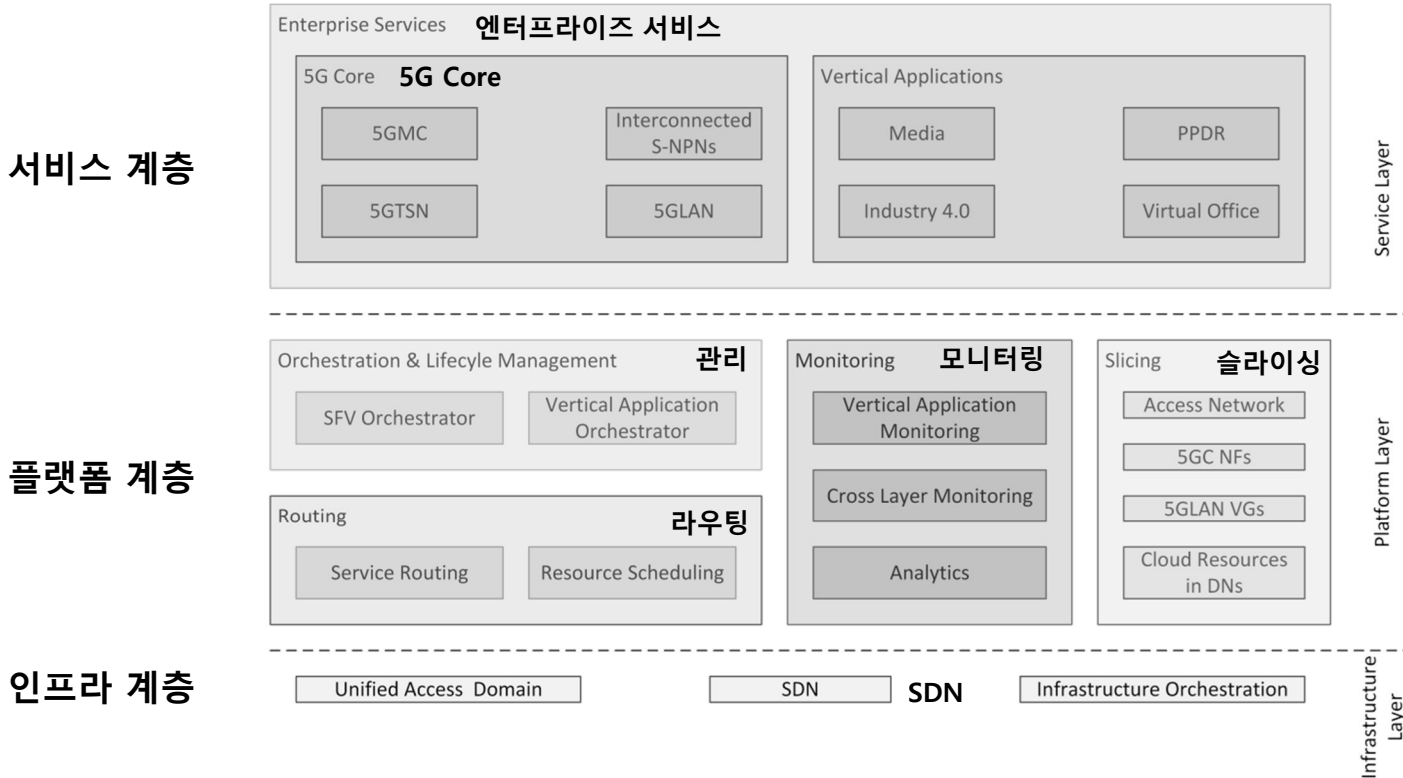
Source: A Tutorial on Trusted and Untrusted non-3GPP Accesses in 5G Systems, Mario T. Lemes ID , Cristiano B. Both ID , Antonio Oliveira Jr. ID , and Kleber V. Cardoso ID





# DAY 1: 5G 네트워크 개요

## ❖ 5G 하이레벨 시스템 구성 (예): FUDGE-5G

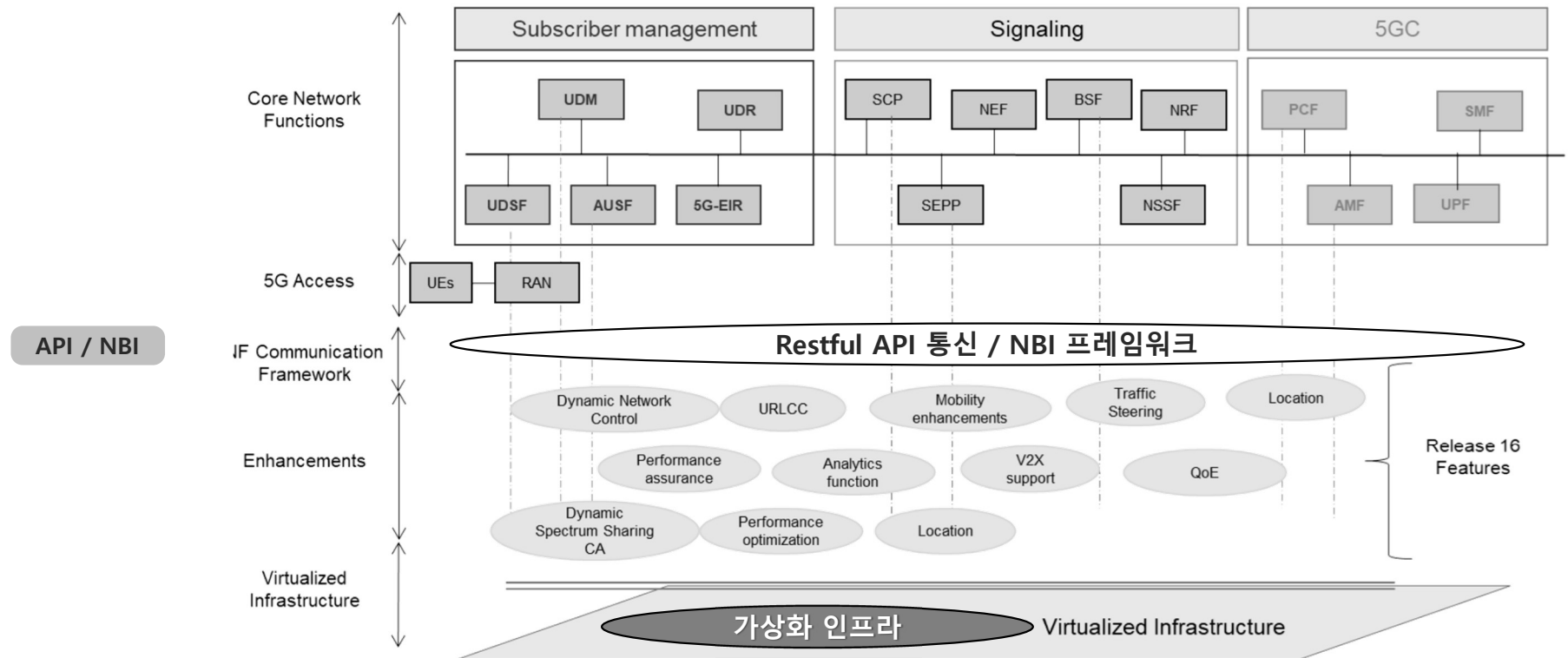


Source: 5GPPP Architecture Working Group, 5G Architecture White Paper



# DAY 1: 5G 네트워크 개요

## ❖ Enhancements supporting verticals (예: Release 16 5G features)



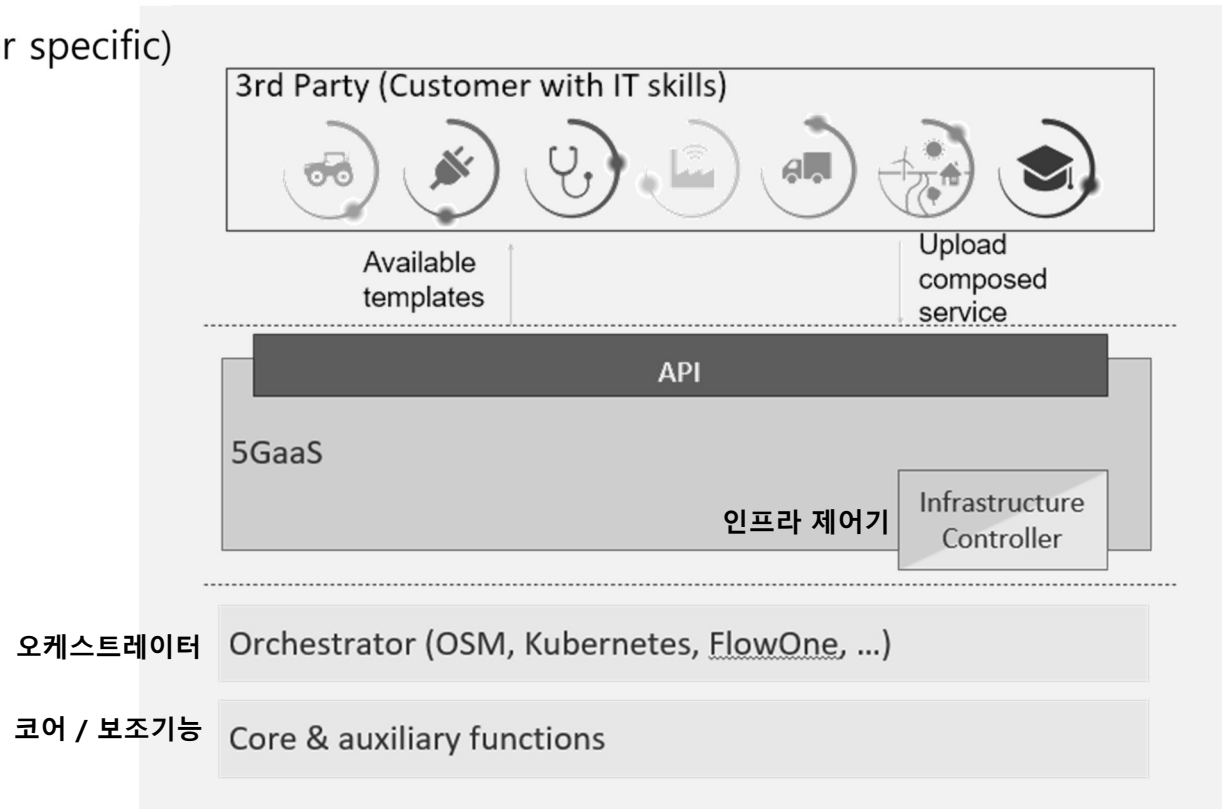
Source: 5GPPP Architecture Working Group, 5G Architecture White Paper



# DAY 1: 5G 네트워크 개요

## ❖ 5GaaS (5G as a Service) diagram

- 운영의 변화 (where yellow is operator specific)
  - 인프라 제어기 부분
  - 오케스트레이터
  - 코어 등의 기능



Source: 5GPPP Architecture Working Group, 5G Architecture White Paper



# DAY 1: 5G 네트워크 개요

## ❖ Deploying 5G core network (예: Free5GC @ Kubernetes and Helm)

```

root@5g:~# helm show values towards5gs/free5gc
#
# Software Name : towards5gs-helm
# SPDX-FileCopyrightText: Copyright (c) 2021 Orange
# SPDX-License-Identifier: Apache-2.0
#
# This software is distributed under the Apache License 2.0,
# the text of which is available at todo
# or see the "LICENSE" file for more details.
#
# Author: Abderaouf KHICHANE, Ilhem FAJJARI, Ayoub BOUSSELMI
# Software description: An open-source project providing Helm charts to deploy 5G components
# (Gore + RAN) on top of Kubernetes
#
# Default values for free5gc-chart.
# This is a YAML-formatted file.
# Declare variables to be passed into your templates.

global:
  name: free5gc
  userPlaneArchitecture: single # possible values are "single" and "ulcl"
  nrf:
    service:
      name: nrf-nnrf
      type: ClusterIP
      port: "8000"
      nodePort: "30800"
  sbi:
    scheme: http

amf:
  n2if: # NGAP
    ipAddress: 10.100.50.249
  service:
    ngap:
      enabled: false
      name: amf-n2
      port: 38412
      nodeport: 31412
      protocol: SCTP
      type: NodePort
  smf:
    n4if:
      ipAddress: 10.100.50.244
#Global network parameters
n2network:
  name: n2network
  masterIf: eth0
  subnetIP: 10.100.50.248
  cidr: 29
  gatewayIP: 10.100.50.254
  excludeIP: 10.100.50.254
n3network:
  name: n3network
  masterIf: eth0
  subnetIP: 10.100.50.232
  cidr: 29
  gatewayIP: 10.100.50.238
  excludeIP: 10.100.50.238
n4network:
  name: n4network
  masterIf: eth0
  subnetIP: 10.100.50.240
  cidr: 29
  gatewayIP: 10.100.50.246
  excludeIP: 10.100.50.246

n6network:
  name: n6network
  masterIf: eth1
  subnetIP: 10.100.100.0
  cidr: 24
  gatewayIP: 10.100.100.1
  excludeIP: 10.100.100.254

n9network:
  name: n9network
  masterIf: eth0
  subnetIP: 10.100.50.224
  cidr: 29
  gatewayIP: 10.100.50.230
  excludeIP: 10.100.50.230

# These parameters can be used to
# enable/disable deployment of subcharts
deployMongoDB: true
deployAMF: true
deployAUSF: true
deployN3IWF: false
deployNRF: true
deployNSSF: true
deployPCF: true
deploySMF: true
deployUDM: true
deployUDR: true
deployUPF: true
deployWEBUI: true

# Disable the deployment of mongodb as an NRF
# subchart
free5gc-nrf:
  db:
    enabled: false

# This section can be used to override the
# default values in the MongoDB chart (remember
# MongoDB is a subchart of the
# free5gcControlplane chart since control plane
# NFs rely on it.
mongodb:
  fullnameOverride: "mongodb"
  useStatefulSet: true
  auth:
    enabled: false
  persistence:
    size: 6Gi
    mountPath: /bitnami/mongodb/data/db/
  service:
    name: mongodb
    type: ClusterIP
    port: 27017
    nodePort: "30017"

```

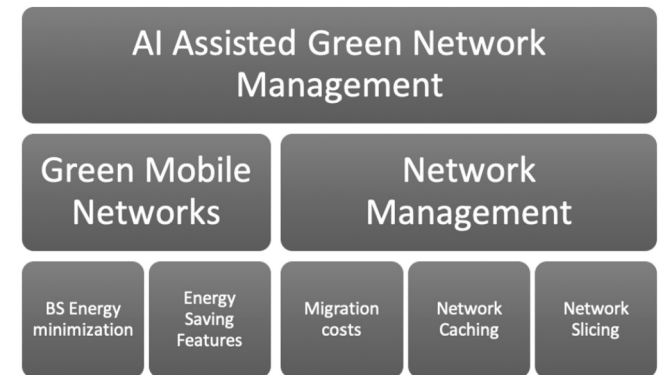
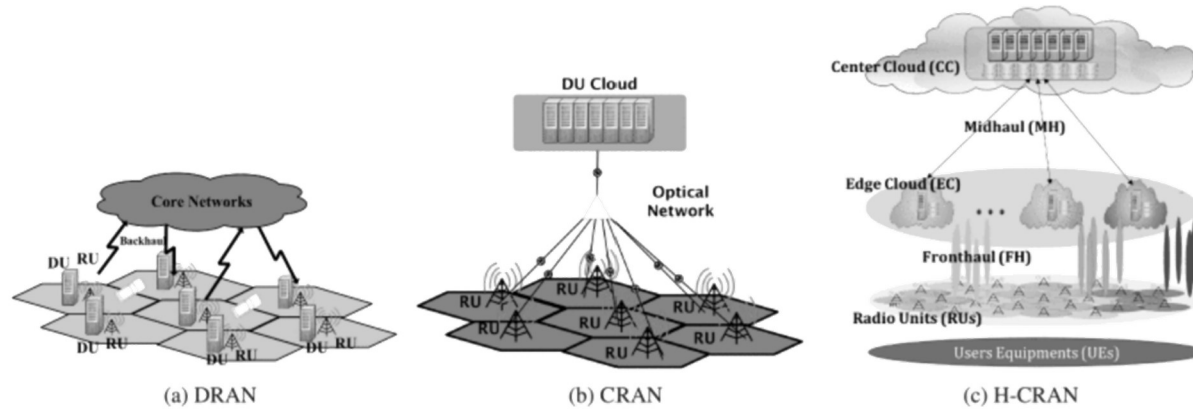
Note: [https://helm.sh/docs/intro/using\\_helm/](https://helm.sh/docs/intro/using_helm/)



# DAY 1: 5G 네트워크 개요

## ❖ Data Driven AI Assisted Green Network Design and Management

- DRAN
- CRAN
- H-CRAN

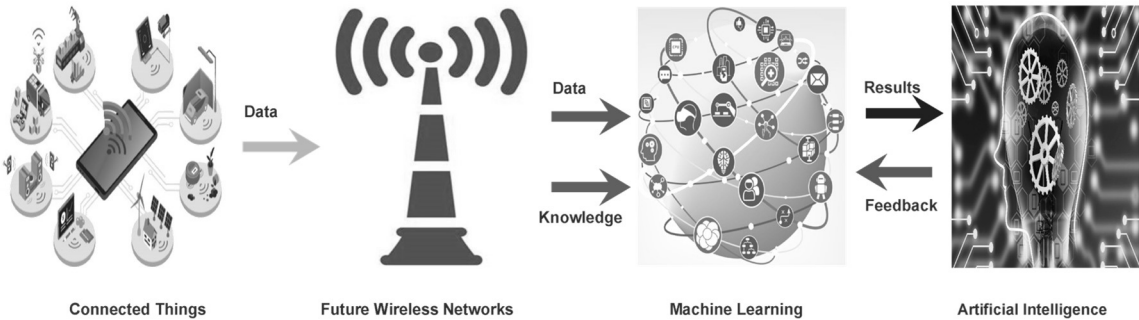


Source: [http://kth.diva-portal.org/smash/get/diva2:1626735/FULLTEXT01.pdf?fbclid=IwAR1F1GIV3bU\\_YONZzxElTb4kp\\_Y7t70VczSb\\_0abIVqJZxt2ErbJ60UuAg](http://kth.diva-portal.org/smash/get/diva2:1626735/FULLTEXT01.pdf?fbclid=IwAR1F1GIV3bU_YONZzxElTb4kp_Y7t70VczSb_0abIVqJZxt2ErbJ60UuAg)



# DAY 1: 5G 네트워크 개요

## ❖ ML-based solution for 5G network.



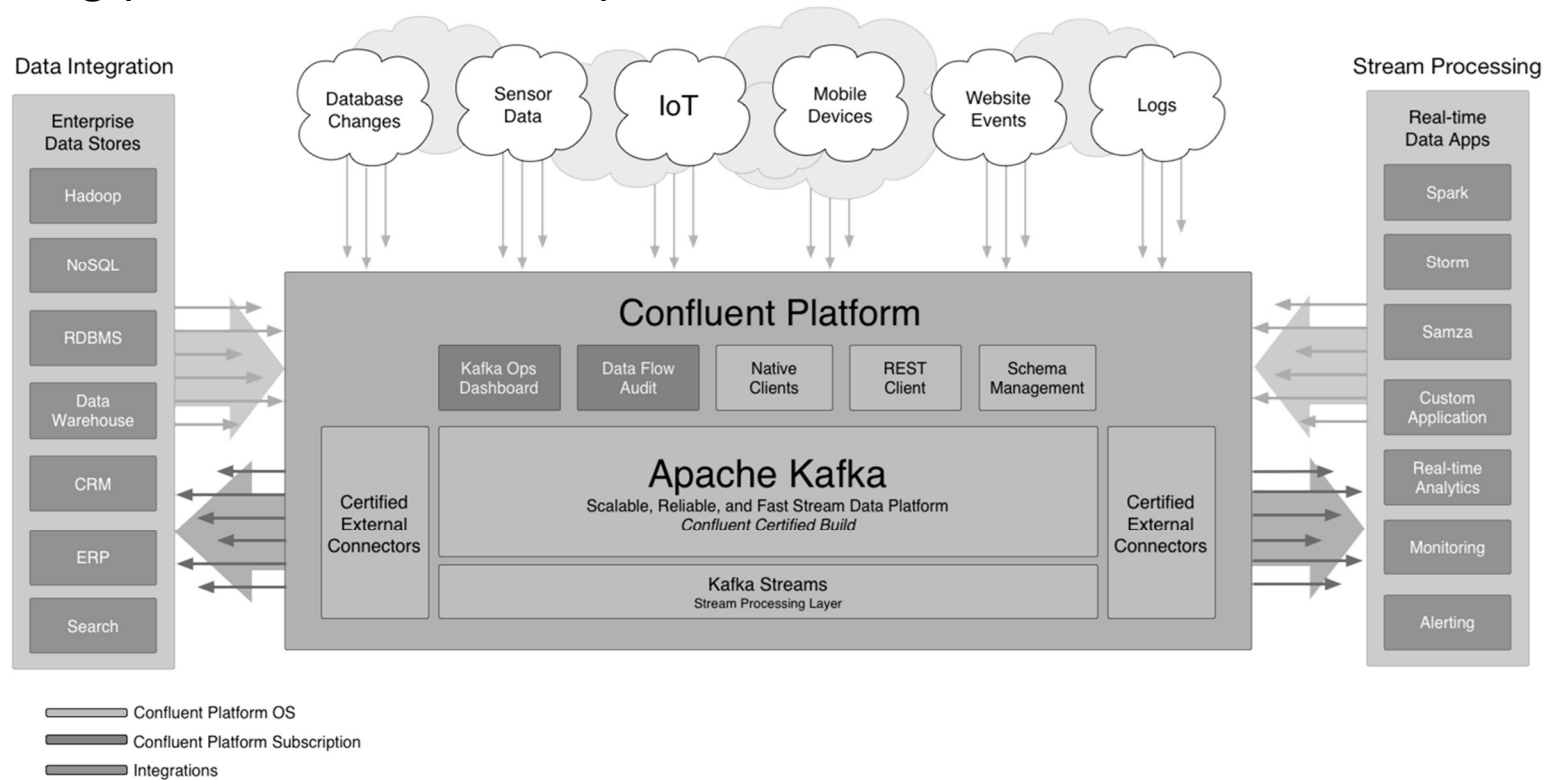
Source: <https://www.mdpi.com/1424-8220/22/1/26/htm>

Author References	적용 분야 Key Contribution	적용 방법 ML Applied	Network Participants Component		5G Network Application Parameter				
			RAN	Core	LB	SDN	RAN	RA	SEC
Alave et al. [68]	Network traffic prediction	LSTM and DNN	✓	✓	*	✓	✓	✓	X
Bega et al. [15]	Network slice admission control algorithm	Machine Learning and Deep Learning	✓	X	X	✓	✓	✓	X
Suomalainen et al. [69]	5G Security	Machine Learning	X	✓	✓	✓	✓	✓	✓
Bashir et al. [70]	Resource Allocation	Machine Learning	✓	✓	✓	✓	✓	✓	X
Balevi et al. [71]	Low Latency communication	Unsupervised clustering	X	✓	X	✓	✓	✓	X
Tayyaba et al. [72]	Resource Management	LSTM, CNN, and DNN	✓	✓	X	✓	✓	✓	✓
Sim et al. [73]	5G mmWave Vehicular communication	FML (Fast machine Learning)	X	✓	*	✓	✓	✓	X
Li et al. [74]	Intrusion Detection System	Machine Learning	X	✓	X	✓	✓	✓	✓
Kafle et al. [75]	5G Network Slicing	Machine Learning	X	✓	X	✓	✓	✓	✓
Chen et al. [76]	Physical-Layer Channel Authentication	Machine Learning	X	✓	X	X	X	X	✓
Sevgican et al. [77]	Intelligent Network Data Analytics Function in 5G	Machine Learning	✓	X	✓	X	X	*	*



# DAY 1: 5G 네트워크 개요

## ❖ Stream Processing (예: Confluent Platform)



Source: <https://docs.confluent.io/2.0.0/platform.html>



# DAY 1: 5G 네트워크 개요

## ❖ KOREN 기반 5G Testbeds

### • 5G 오픈테스트랩 개요





# DAY 1: 5G 네트워크 개요

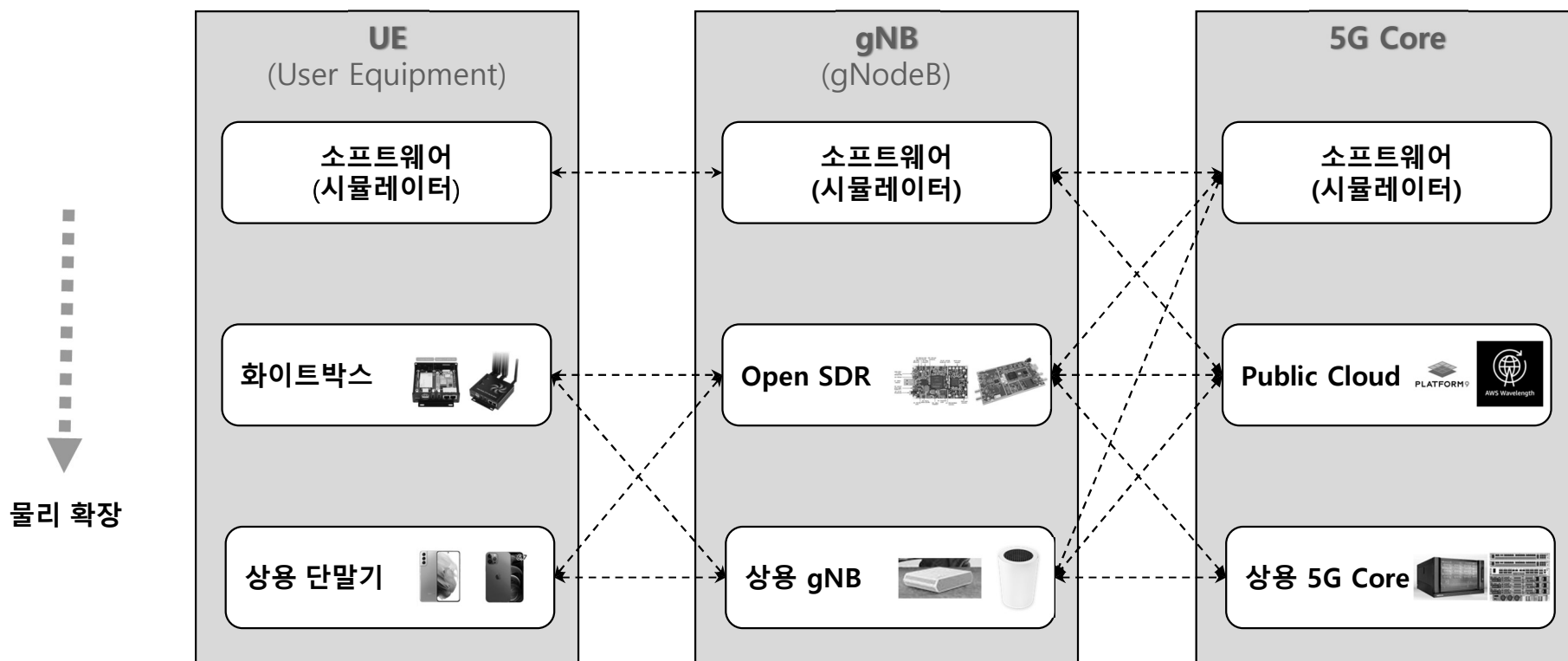
## ❖ KOREN 기반 5G Testbeds

- 공인인증 테스트 지원



# DAY 1: 5G 네트워크 개요

## ❖ 5G 네트워크 인프라 구성 (시험/개발/구축)



# DAY 1: 5G 네트워크 개요

## ❖ 5G 네트워크 인프라 구성 (시험/개발/구축 기능 연계)

The screenshot shows the KubeSphere Workbench interface. On the left sidebar, the 'Namespace' menu item is highlighted with a dashed box. The main area displays a table of services in the 'default' namespace. The '노출 Port' (Exposed Port) column is highlighted with a dashed box. A context menu is open over the '노출 Port 지정' (Exposed Port Designation) column, with the '노출 Port 지정' option highlighted.

Service Name	Namespace	IP Address	Port	Protocol	Creation Time
webui-service	default	10.233.35.142	30500	TCP	2022-07-01 01:38:08
udr-nudr	default	10.233.2.107	-	-	2022-07-01 01:38:08
udm-nudm	default	10.233.48.151	-	-	2022-07-01 01:38:08
smf-nsmf	default	10.233.49.167	-	-	2022-07-01 01:38:08
pcf-npcf	default	10.233.61.136	-	-	2022-07-01 01:38:08
nssf-nssf	default	10.233.34.190	-	-	2022-07-01 01:38:08



# DAY 1: 5G 네트워크 개요

## ❖ 5G 코어 오픈소스 비교 (Conformance tests)

- free5GC
- Open5GS
- OAI

Procedures on testing	Protocols	Messages	free5GC	Open5GS	OAI
			free5GC	Open5GS	OAI
Registration	NAS	Registration Request, Registration Accept, and Registration Complete	✓	✓	✓
Primary authentication and key agreement	NAS	Authentication Request and Authentication Response	✓	✓	✓
Identification	NAS	Identity Request and Identity Response	✓	✓	✓
Transport	NAS	UL NAS transport and DL NAS transport	✓	✓	✓
Security mode	NAS	Security Mode Command and Security Mode Complete	✓	✓	✓
Generic UE configuration update	NAS	Configuration Update Command	✗	✓	✗
Session management	NAS	PDU Establishment Request and PDU Establishment Accept	✓	✓	✓
Interface management	NGAP	NG Setup Request and NG Setup Response	✓	✓	✓
Transport NAS messages	NGAP	Downlink NAS Transport and Uplink NAS Transport	✓	✓	✓
UE context management	NGAP	Initial Context Setup Request and Initial Context Setup Response	✓	✓	✓
PDU session management	NGAP	PDU Session Resource Setup Request and PDU Session Resource Setup Response	✓	✓	✓

Source: Tutorial on communication between access networks and the 5G core, IDLab—Department of Applied Engineering, University of Antwerp—IMEC, Antwerp, Belgium



# DAY 1: 5G 네트워크 개요

## ❖ 5G 코어 오픈소스 비교 (Robustness tests)

- free5GC
- Open5GS
- OAI

free5GC

Open5GS

OAI

Name	Protocols	Procedures involved	Messages	free5GC	Open5GS	OAI
Registration	NAS	Registration	Registration Request and Registration Reject	✗	✓	✗
Authentication	NAS	Primary authentication and key agreement	Authentication Request, Authentication Response, Authentication Failure and Authentication Reject	✓	✓	✓
Security	NAS	Security mode, Registration and Identification	Security Mode Command, Security Mode Complete, Registration Reject, Identity Request and Identity Response	✗	✗	✗
SMF selection	NAS	Transport	UL NAS Transport and DL NAS Transport	✓	✗	✗
UPF selection	NAS	Transport, Session management	UL NAS Transport, DL NAS Transport, PDU Establishment Request and PDU Establishment Reject	✓	✓	✓
NAS flow validate	NAS	Security mode, Transport, Session management and Registration	Security Mode Command, UL NAS Transport, PDU Session Establishment Request, Security Mode Complete and Registration Accept	✓	✓	✗
Interface management	NGAP	Interface Management	NG Setup Request and NG Setup Failure	✓	✓	✗

Source: Tutorial on communication between access networks and the 5G core, IDLab—Department of Applied Engineering, University of Antwerp—IMEC, Antwerp, Belgium



# DAY 1: 5G 네트워크 개요

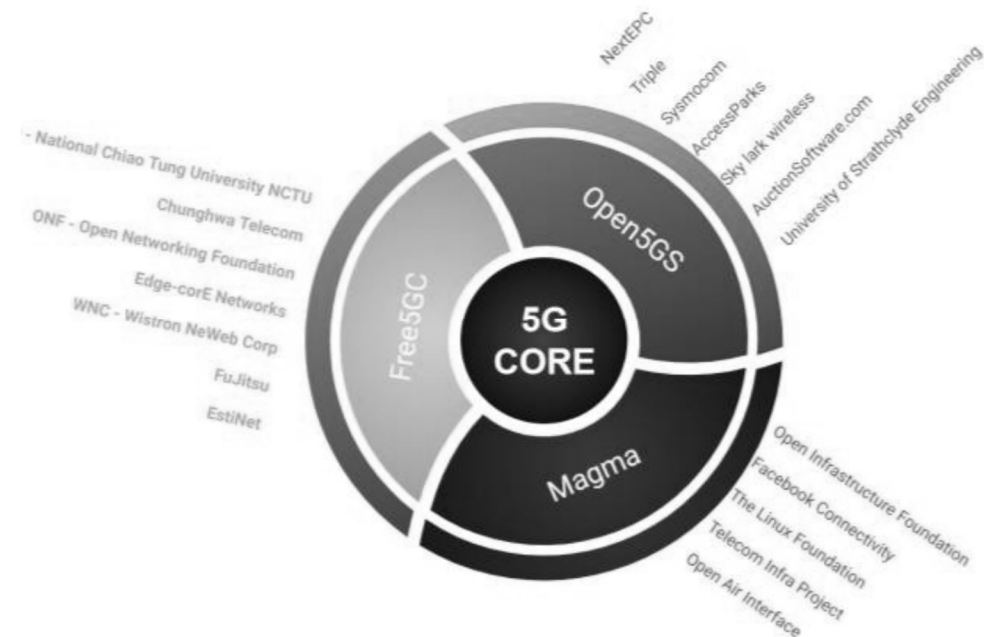
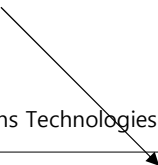
- ❖ 5G Core 오픈소스 비교 (예: free5GC vs Open5GS vs magma)
- ❖ 'Analysis for Comparison of Framework for 5G Core Implementation

- Magma
- Open5GS
- Free5GC

TABLE I. ELEMENTS NECESSARY TO DEPLOY

Magma	Open5GS	Free5GC
Docker/Container + bare metal	Docker/Container	Virtual Machine

K8s 시연 구성



Source: 2021 International Conference on Information Science and Communications Technologies (ICISCT) | 978-1-6654-3258-0/21/\$31.00 ©2021 IEEE | DOI: 10.1109/ICISCT52966.2021.9670414



# DAY 1: 5G 네트워크 개요

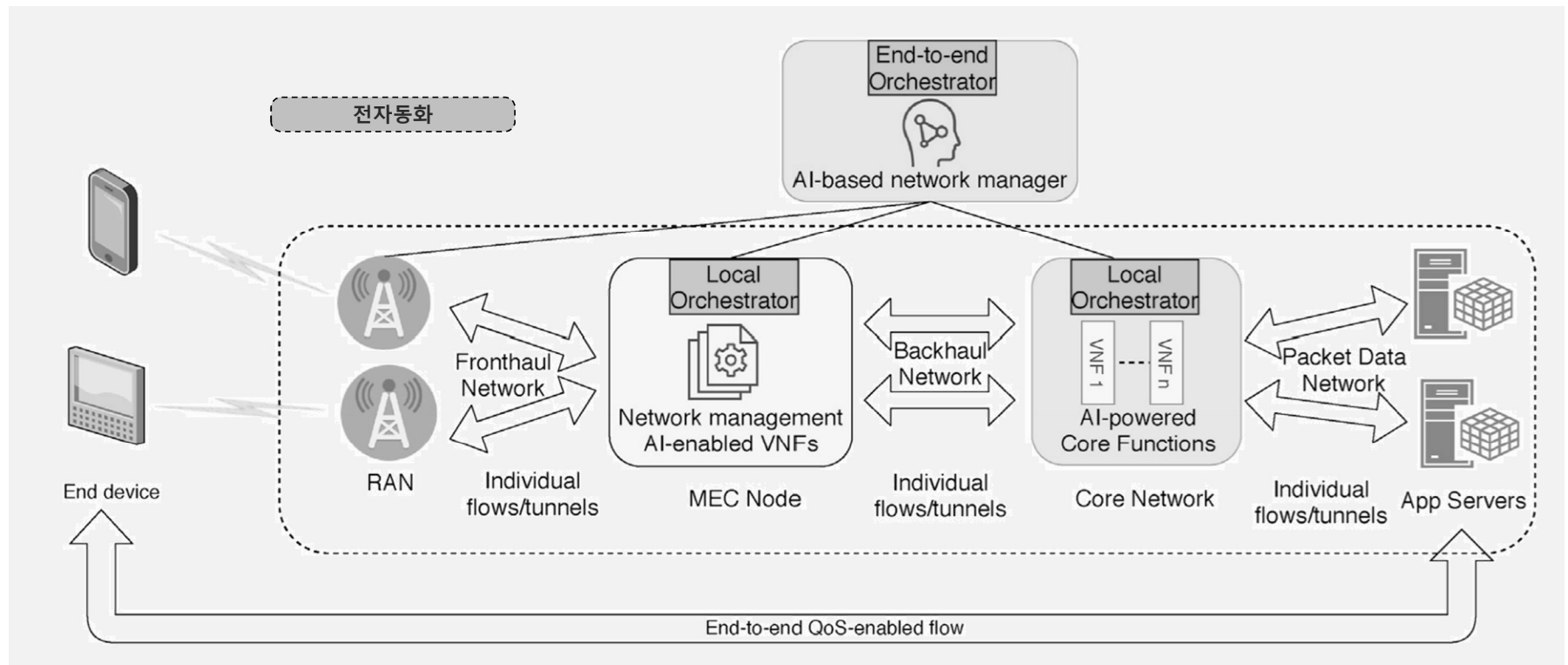
## ❖ 5G Core 오픈소스 비교 (예: free5GC vs Open5GS vs magma)

항목	free5GC	Open5GS	magma
UE 등록, 인증, 세션확립 및 패킷 전송	3GPP Release15.3	3GPP Release16	3GPP Release15
슬라이스 식별자 단위 라우팅 및 품질 제어	슬라이스 식별자로 UPF 배분 가능, 품질 제어(QoS)는 구현되지 않음	슬라이스 식별자로 UPF 배분 가능 품질 제어(QoS)는 구현되지 않음	슬라이스 분배 미실장 DNN*1 단위로 우선 제어는 가능
CU 분리	5G 코어 네트워크에서 UPF를 분리 구축 가능	5G 코어 네트워크에서 UPF를 분리 구축 가능	C / U를 분리하지 않고 소형 일체형 텐테나화하여 배치
MEC 분배(ULCL)	각 IMSI에 대해 대상 IP 주소로 배분 가능	미실행	MSI마다 5tuple로 배분 가능
전송 성능 (1G 인터페이스) ※RAN/UE 및 트래픽 부하는 계측기를 사용	DL:916Mbps, UL:932Mbps (롱 패킷: 1400byte UDP) DL:36Mbps, UL:116Mbps (짧은 패킷: 66byte UDP)	미시험	미시험
동시 접속 UE 수	11UE까지		
UE ( SIM )	GUI에서 UE 등록, 업데이트, 삭제	GUI에서 UE 등록, 업데이트, 삭제	GUI에서 UE 등록, 업데이트, 삭제
구성 설정, 모니터링, 운영	<ul style="list-style-type: none"> <li>구성 설정은 Yaml 파일을 직접 편집합니다. 필요, 편집 부분을 많이 이해하기 어렵다.</li> <li>알람은 시스템 로그 파일에서 확인</li> </ul>	<ul style="list-style-type: none"> <li>구성 설정은 Yaml 파일을 편집해야 합니다. 편집 부분을 많이 이해하기 어렵다.</li> <li>알람은 시스템 로그 파일보다 확실합니다.</li> </ul>	오케스트레이터로 관리 제어, GUI에 구성 설정 및 상태 모니터링 가능
도입 용이성	요구 하드웨어 사양 낮음, 매뉴얼대로 도입 간단	요구 하드웨어 사양 낮음, 매뉴얼대로 도입 간단	요구 하드웨어 사양 낮음, 매뉴얼대로 도입 간단
4G RAN과 5G RAN을 동시 수용	5G 코어만 구현하므로 4G RAN 수용 불가	4G 코어와 5G 코어 모두 구현	4G, 5G, Wi-Fi 모두 수용 Converged Core 개발 검토 중



# DAY 1: 5G 네트워크 개요

## ❖ Overall Zero-touch Network and Service Management (ZSM) vision.



Machine learning-based zero-touch network and service management, Jorge Gallego-Madrid, Ramon Sanchez-Iborra, Pedro M. Ruiz, Antonio F. Skarmeta

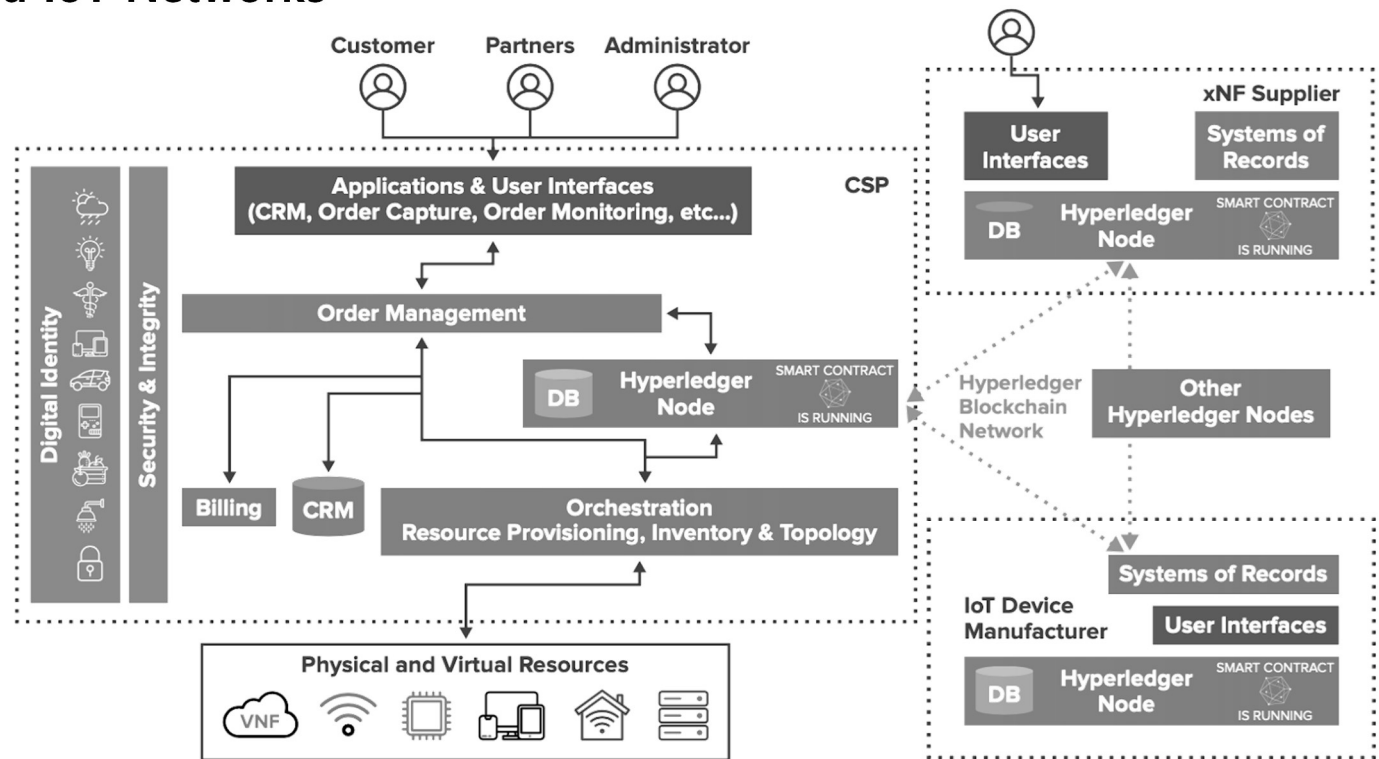




# DAY 1: 5G 네트워크 개요

❖ 블록체인 토폴로지(예): 통신사간 과금 (Inter-carrier Charges @ Telecom)

- (예) Hyperledger-based IoT Networks



Source: <https://www.hyperledger.org/tag/telecom>

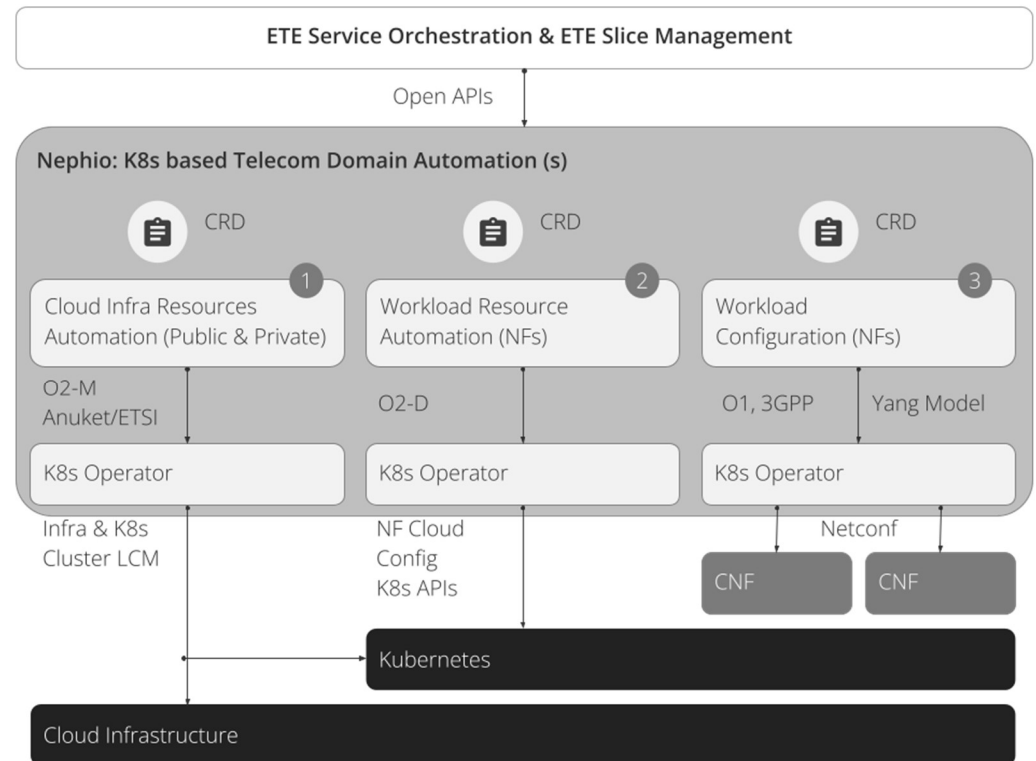


# DAY 1: 5G 네트워크 개요

## ❖ Google, Linux Foundation Launch

### Nephio to Automate 5G

- 네피오 프로젝트: Nephio 프로젝트는 통신 사업자가 대규모 에지 배포에서 멀티 벤더 클라우드 인프라와 네트워크 기능을 더 쉽게 배포하고 관리할 수 있도록 Kubernetes 기반 클라우드 네이티브 인텐트 자동화 및 자동화 템플릿을 제공하도록 설계되었다. 이 템플릿은 운영자가 직접 제어하거나 Google Config Connector, AWS(Amazon Web Services)의 Kubernetes용 컨트롤러, Azure Service Operator와 같은 하이퍼스케일러 기반 플랫폼에서 제어하는 Kubernetes 서브스트레이트 상에 위치한다.



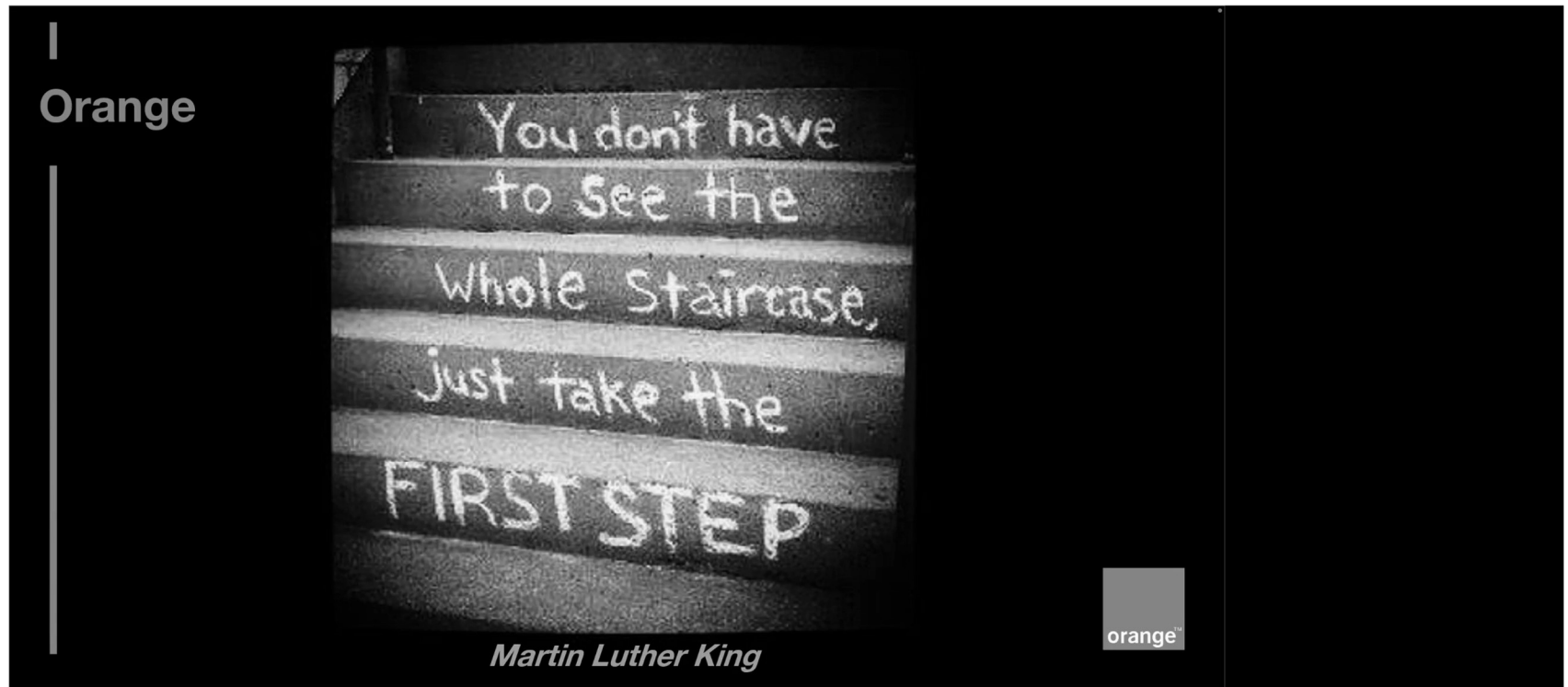
Source: <https://wiki.nephio.org/display/HOME/Overview+of+Nephio>

Source: <https://www.sdxcentral.com/articles/news/google-linux-foundation-launch-nephio-to-automate-5g/2022/04/>



# DAY 1: 5G 네트워크 개요

❖ You don't have to see the whole staircase, just take the **FIRST STEP**. (Martine Luther King)





**THANK  
YOU**

