5G 네트워크

(Day 1. 5G 네트워크 기술)

2022년 7월
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- Day 1: 5G 네트워크 기술
- 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

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➢ (별도) Day 4~5 시연/실습

- 개요
- 5 Nodes in One-box Lab (시연)
- 2 Box Lab (실습)
- Cloud Native 5G Network Testbed (실습)

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➢ Day 1: 5G 네트워크 기술

- 개요
- 아키텍처
- Non-Standalone(NSA), Standalone(SA)
- 계층별 구성(HW, 가상화, Cloud)
- 오픈소스/제조사

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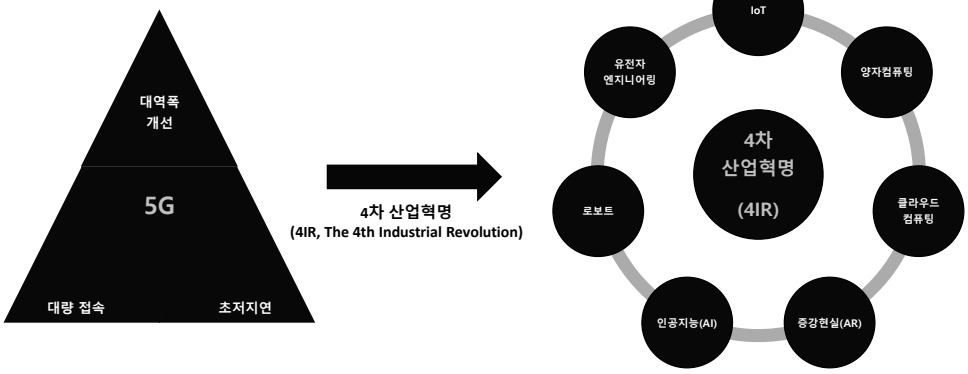
DAY 1: 5G 네트워크 기술

❖ 5G Enablers 4IR

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



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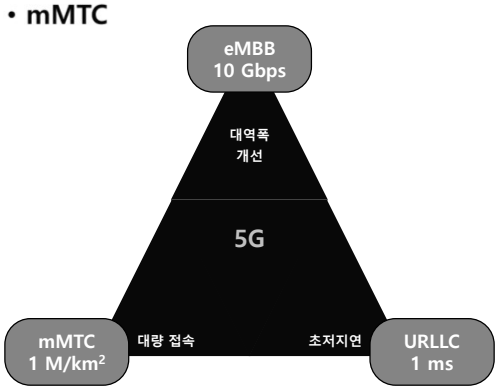
❖ 5G Enablers 4IR

• eMBB
• URLLC
• mMTC



Generation	Maximum Download Speed	Typical Download Speed
2G	100 to 300 Kbps	<100 to 100 Kbps
3G	0.3 to 42 Mbps	0.1 to 8 Mbps
4G	150 to 979 Mbps	15 to 90 Mbps
5G	1 to 10 Gbps	150 to 200 Mbps
6G*	8 Tbps	Unknown

*not defined nor deployed; this is estimated data download speed.

eMBB (enhanced Mobile Broadband)**; URLLC** (Ultra Reliable Low Latency Communications)**; mMTC** (massive Machine Type Communications)

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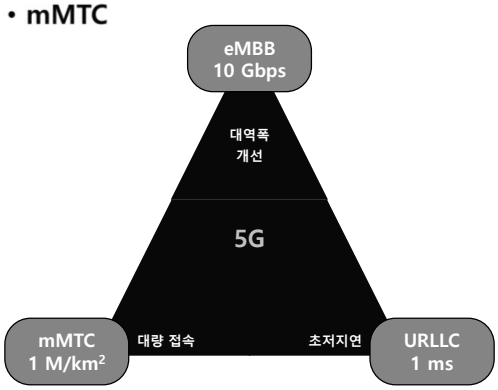
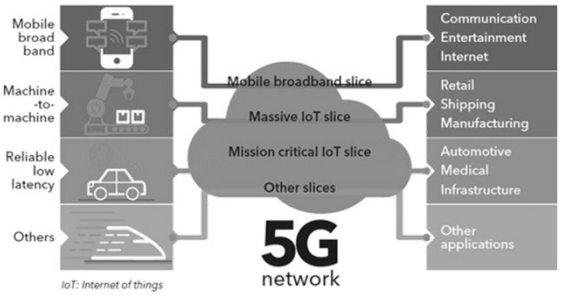
❖ 5G Enablers 4IR

- eMBB
- URLLC
- mMTC



5G network slicing



eMBB (enhanced Mobile Broadband)**; URLLC** (Ultra Reliable Low Latency Communications)**; mMTC** (massive Machine Type Communications)

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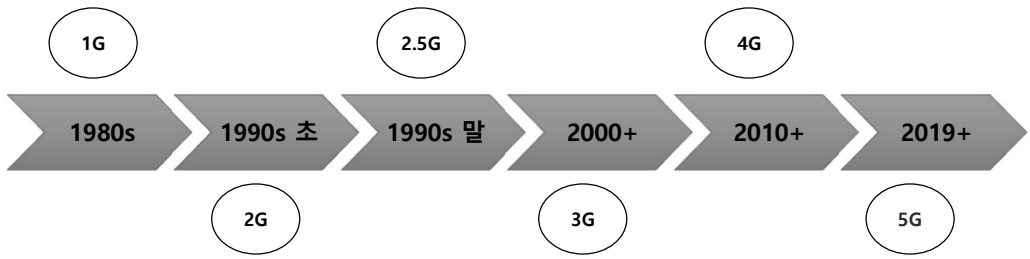
DAY 1: 5G 네트워크 기술

❖ 모바일 기술 발전과 3GPP

3GPP(3rd Generation Partnership Project): 이동통신 관련 단체들 간의 공동 연구 프로젝트로 국제전기통신연합(ITU)의 IMT-2000 프로젝트의 범위 내에서 - 전 세계적으로 적용 가능한 - 3세대 이동통신 시스템 규격의 작성을 목적으로 하고 있다. 3GPP 규격은 진보된 GSM 규격에 기반을 두고 있으며, 무선(radio)과 코어 네트워크(core network), 서비스 구조(service architecture)를 모두 표준화 범위에 포함시키고 있다.



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❖ 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)

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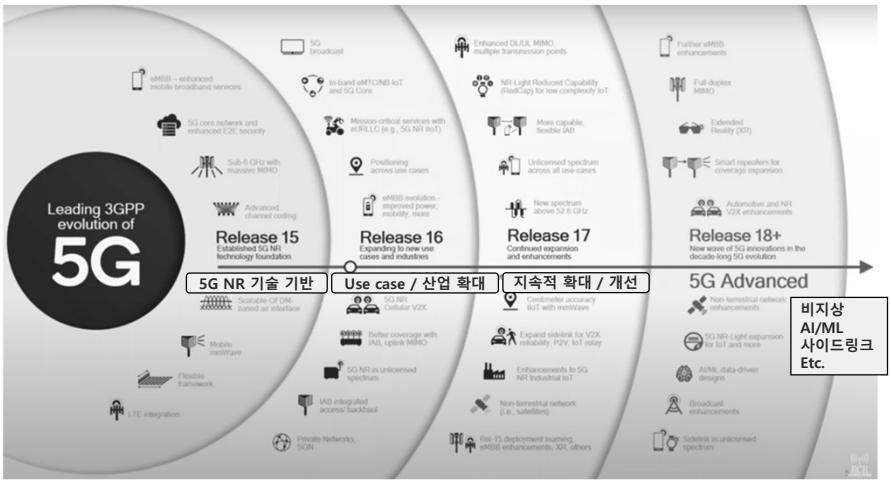
❖ 3GPP 표준

• Rel 15/16/17
• Rel 18 (5G Advanced)



Source: Image courtesy of Qualcomm Technologies, Inc.

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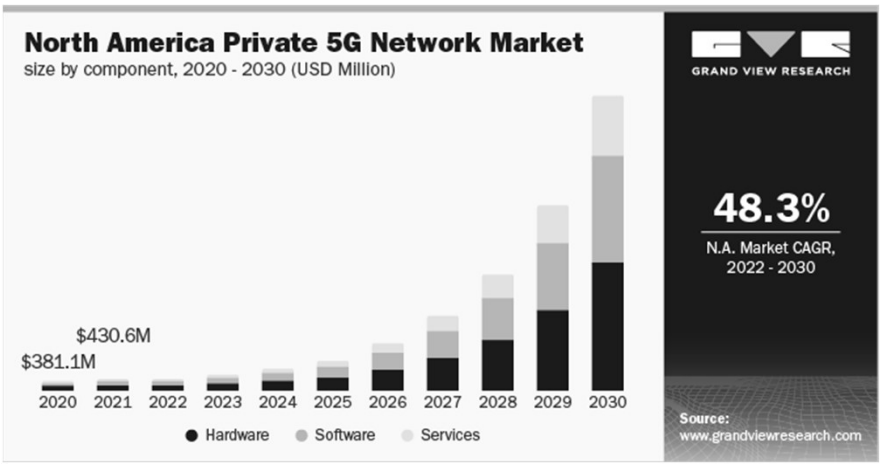
❖ Private 5G Network Market Size, Share & Trends Analysis Report



Source: https://www.grandviewresearch.com/industry-analysis/private-5g-network-market

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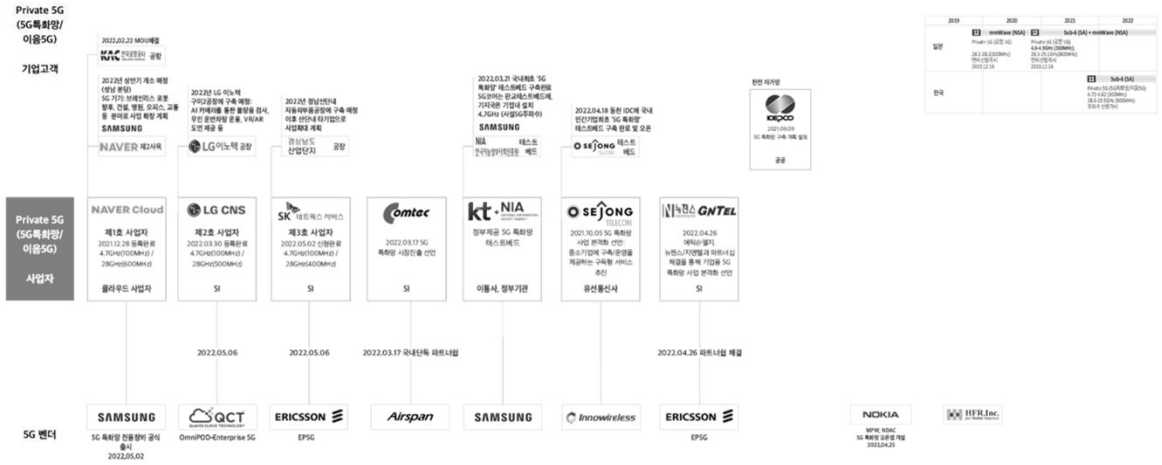
❖ Private 5G 실증/구축/상용서비스: 기업고객 - Private 5G사업자 - 5G벤더 매핑



Source: https://www.netmanias.com/ko/?m=view&id=oneshot&no=15444

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

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

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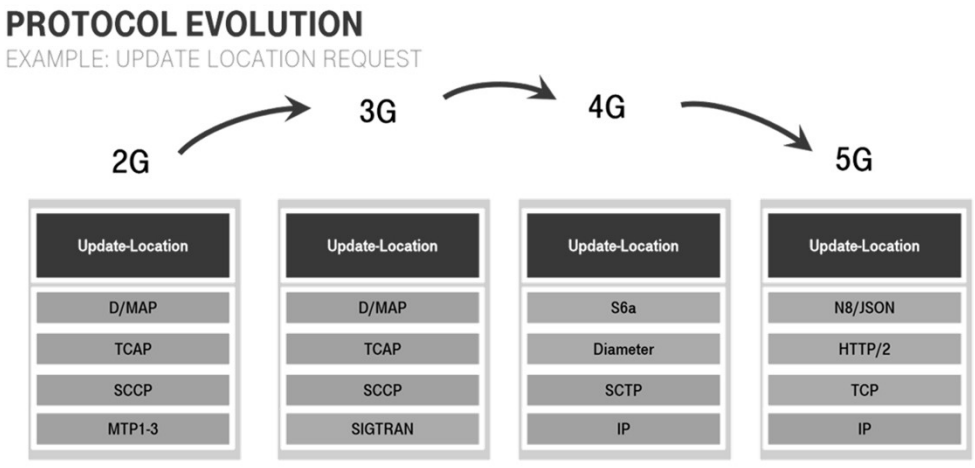
DAY 1: 5G 네트워크 기술

❖ **5G Core procedures run on top of web technologies**



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

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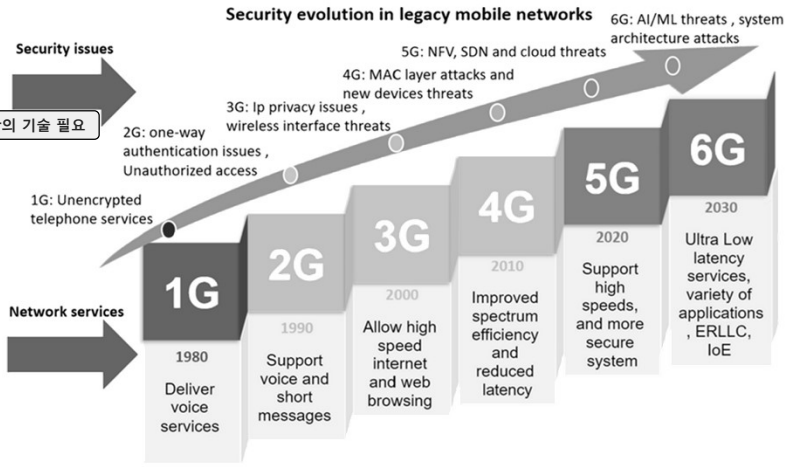
DAY 1: 5G 네트워크 기술

❖ The security evolution of mobile communications from 1G to the predicted future 6G

- 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' Shimaa A. Abdel Hakeem , Hanan H. Hussein and HyungWon Kim, mdpi

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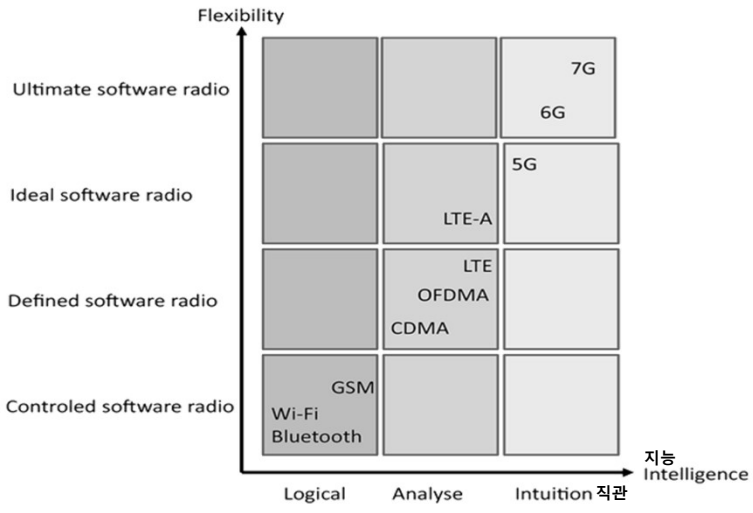
❖ 모바일 네트워크 기술의 발전



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

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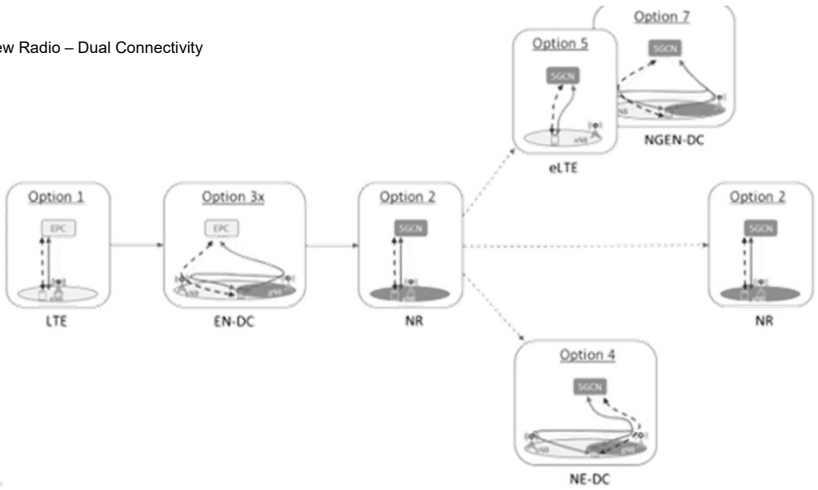
❖ 5G 연결 옵션의 진화 방향

- LTE
- EN-DC
- NR

** **EN-DC**: E-UTRAN New Radio – Dual Connectivity
** **NR:** New Radio



Source: TTA, https://news.v.daum.net/v/20210801060034679?s=print_news

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❖ 적용 옵션 (Deployment options)

		EPC	5GC	
Standalone (SA)	SA	❶ EPC / LTE	❷ 5GC / NR	❺ 5GC / eLTE
Non Standalone (NSA)	NSA	❸ EPC / NR / LTE	❹ 5GC / eLTE / NR	❼ 5GC / NR / eLTE

User Plane
Control Plane

NR – New Radio

** **EN-DC**: E-UTRAN New Radio – Dual Connectivity

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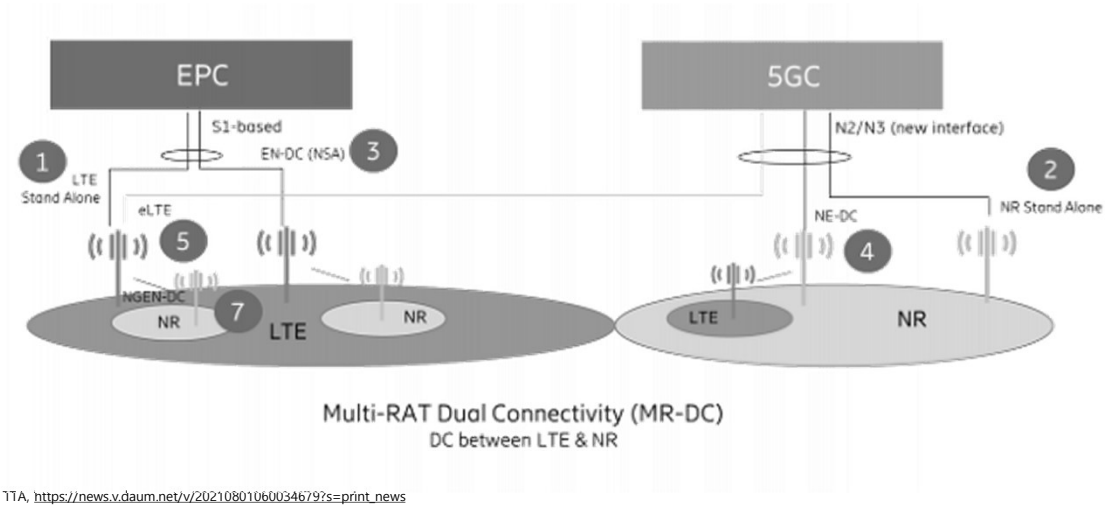
❖ 5G NSA와 진화된 SA 연결옵션



Source: TTA, https://news.v.daum.net/v/20210801060034679?s=print_news

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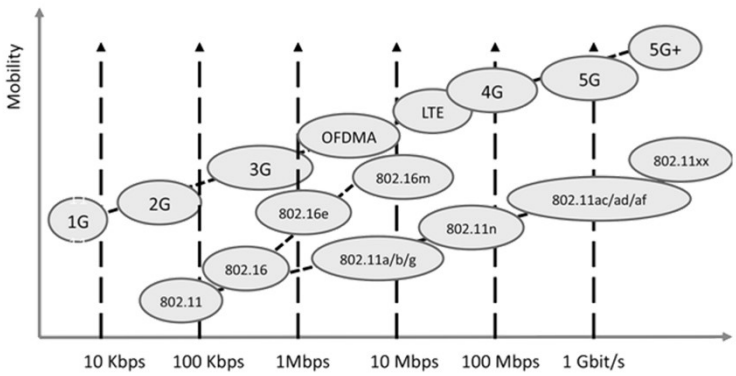
❖ 무선 네트워크의 발전 (Wi-Fi 와 5G)

- The different generations of wireless networks

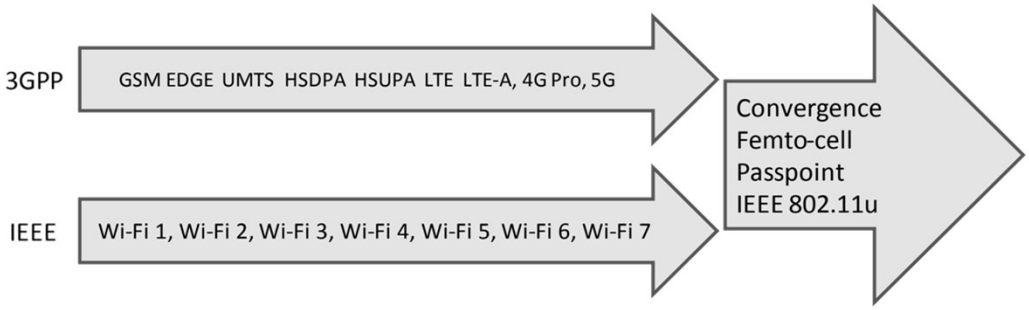


Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

DAY 1: 5G 네트워크 기술

❖ 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

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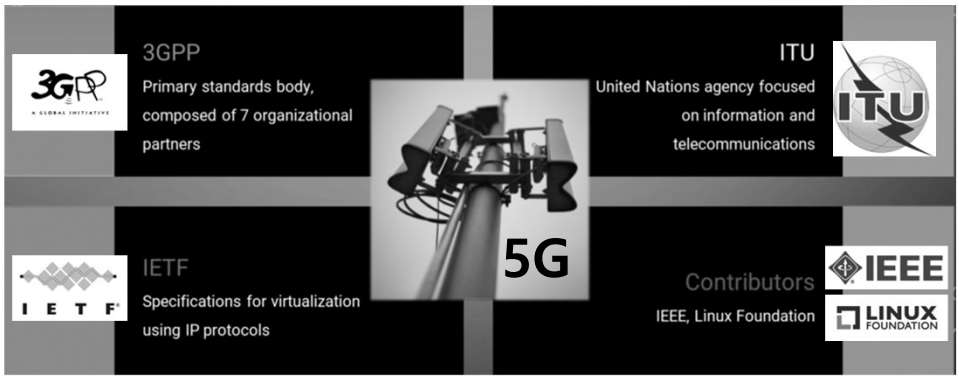
❖ 5G 무선 표준 기관

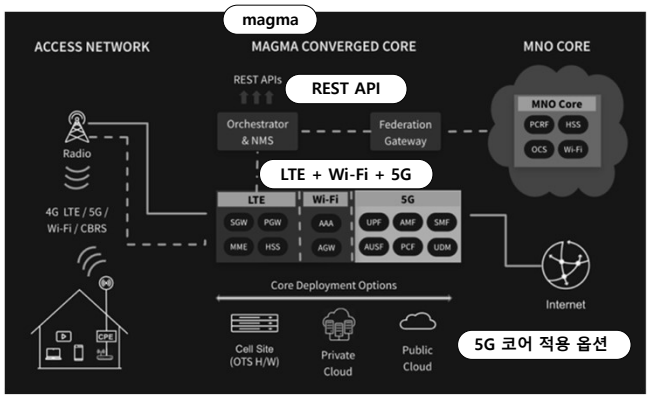
- 3GPP
- ITU
- IETF
- IEEE
- 리눅스 재단
- 기타



DAY 1: 5G 네트워크 기술

❖ 5G 오픈소스 사용 제조사 (예): FreedomFI 사의 5G Core 오픈소스 magma 사용

- **Access Gateway - AGW:** It is a distributed data plane component of the mobile network directly connected to an LTE or to a 5G radio. The Access Gateways are connected to a centralized orchestrator.



Source: https://levelup.gitconnected.com/opensource-5g-core-with-service-mesh-bba4ded044fa

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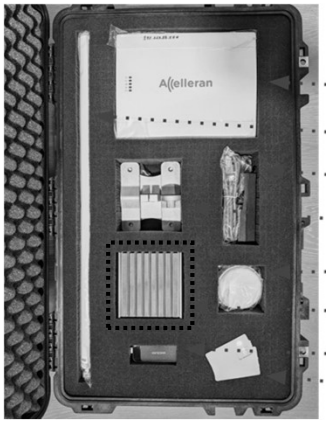
DAY 1: 5G 네트워크 기술

❖ 구축 (예): FreedomFI 사의 5G NSA Core 오픈소스 magma를 사용하는 사설 LTE의 솔루션



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

Citizens Broadband Radio Service (**CBRS**) is a 150 MHz wide broadcast band of the 3.5 GHz band (3550 MHz to 3700 MHz) in the United States.

Source: https://mobile.twitter.com/Open5G

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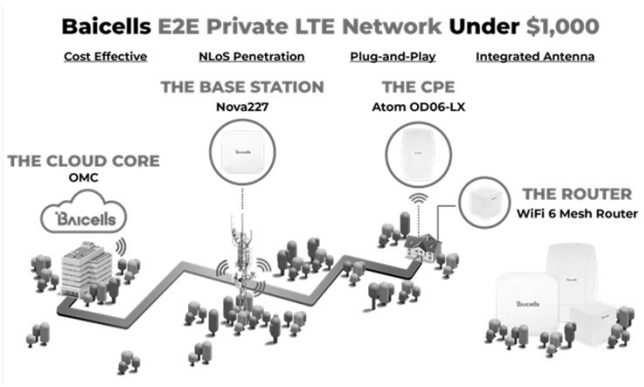
DAY 1: 5G 네트워크 기술

❖ 5G/WiFi 연동 (예): 5G Ready Starter Kit

• Nova227 Starter Kit (pBS2120 x1, EG8013L-M11 x3, SIM cards x3, ER2820 x1)



Magma officially supports auto-configuration of the following devices:
•Baicells Nova-243 Outdoor FDD/TDD eNodeB
- Firmware Version: BaiBS_RTS_3.1.6

•Baicells mBS1100 LTE-TDD Base Station
- Firmware Version: BaiStation_V100R001C00B110SPC003

•Baicells Neutrino-244 ID FDD/TDD enodeB
Magma supports the following management protocols:
•TR-069 (CWMP)
Magma supports configuration of the following data models:
•TR-196 data model
•TR-181 data model

Source: https://store.baicells.com/product/Details?id=82d126c2-90ee-410e-9136-b91d7ab7e9d3&fbclid=IwAR1pJN2aXMTunqvSAoCchTaH7N3BYKHaRAlkRVwhHCAc6i9qVeDVkMiuLgs

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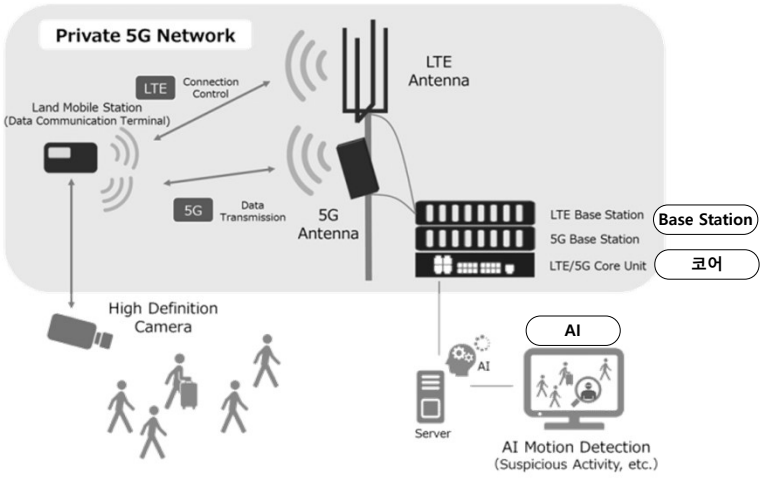
DAY 1: 5G 네트워크 기술

❖ Fujitsu Launches First Commercial Private 5G Network in Japan



Source: https://www.lteto5g.com/fujitsu-launches-first-commercial-private-5g-network-in-japan/

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DAY 1: 5G 네트워크 기술

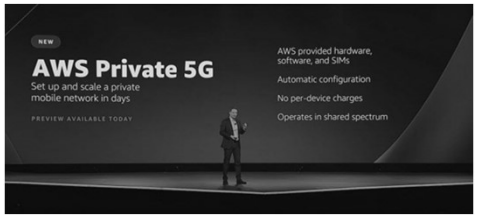
❖ **AWS Private 5G 서비스 (2022)**

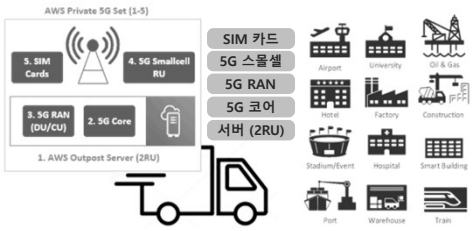
• **AWS가 신청 기업으로 AWS Private 5G망 세트를 배송 (3개의 선택 옵션 제공)**

1) 5G망 Full Set를 기업내에 설치
2) 5G 코어 UPF는 기업내, Control Plane(AMF, SMF,...)은 AWS 클라우드(Region 또는 Local Zone)
3) 기업내에는 RU만 두고 나머지는 모두 AWS 클라우드에 두는 경우.

5G 소프트웨어를 AWS outpost/Local zone/Region에 올려 테스트한 기술 파트너 벤더

- Ericsson,
- Nokia,
- Cisco,
- Mavenir,
- Altiostar,
- Samsung,
- Athonet,
- Celona,
- Druid,
- JMA Wireless 등

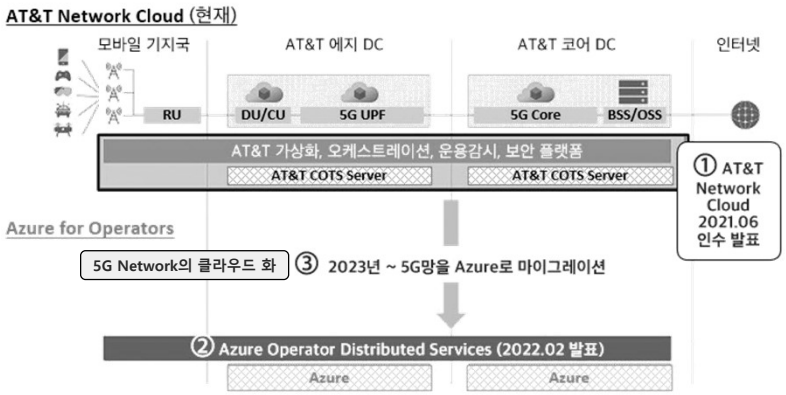




DAY 1: 5G 네트워크 기술

❖ **Microsoft의 이통사 침투 전략 - Azure for Operators**

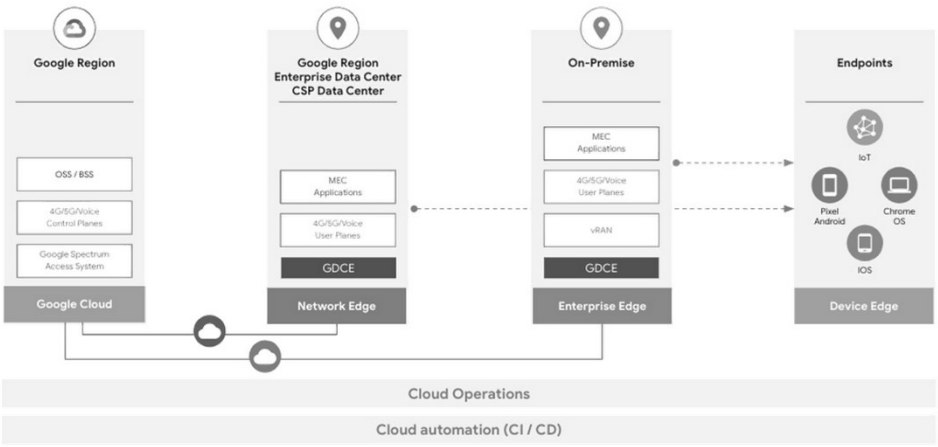
"AT&T Network Cloud" ⇨ "Azure for Operators"로의 마이그레이션



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

DAY 1: 5G 네트워크 기술

❖ Private networking solutions on Google Distributed Cloud Edge and leveraging ecosystem



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

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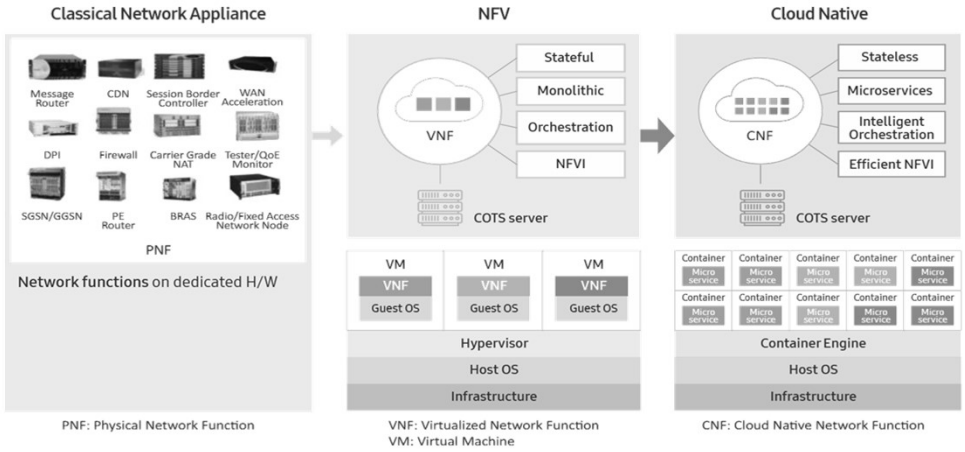
DAY 1: 5G 네트워크 기술

❖ Evolving from dedicated hardware to cloud native architecture



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

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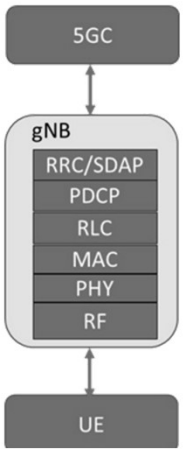
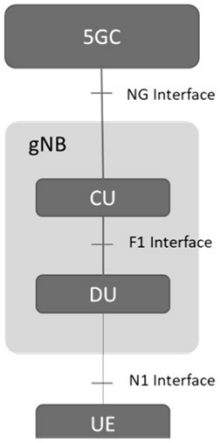
DAY 1: 5G 네트워크 기술

❖ **RAN 구조의 변화 (New C-RAN/Fronthaul)**





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

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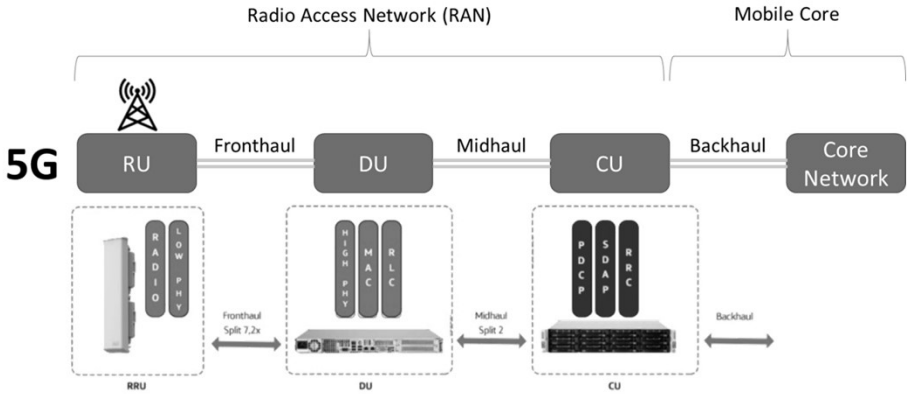
DAY 1: 5G 네트워크 기술

❖ **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/

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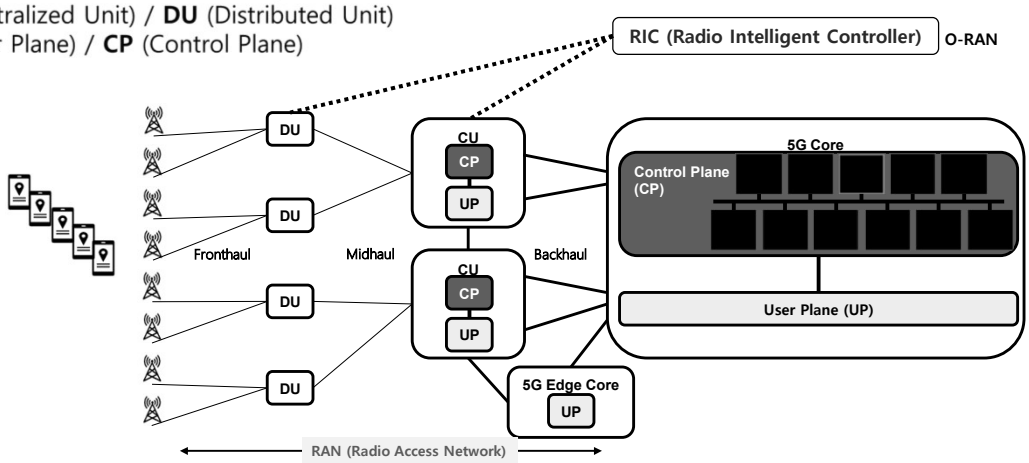
DAY 1: 5G 네트워크 기술

❖ 5G Network Architecture

- **Open Systems Interconnection Layer.**
  - **CU** (Centralized Unit) / **DU** (Distributed Unit)
  - **UP** (User Plane) / **CP** (Control Plane)



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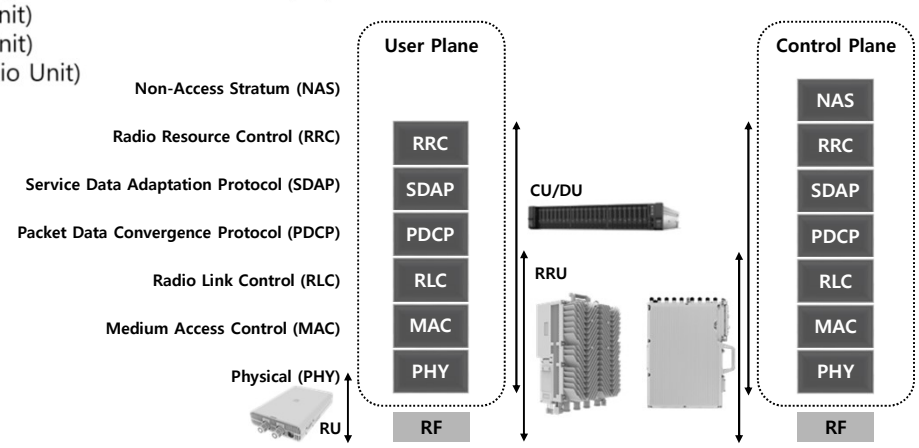
DAY 1: 5G 네트워크 기술

❖ Air Interface

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



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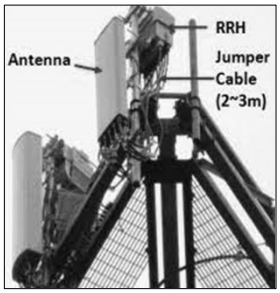
DAY 1: 5G 네트워크 기술

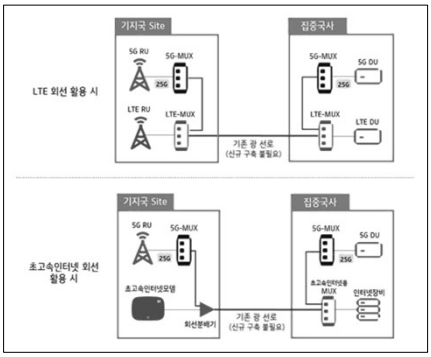
❖ 5G RAN 기기

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



www.netmanias.com

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



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

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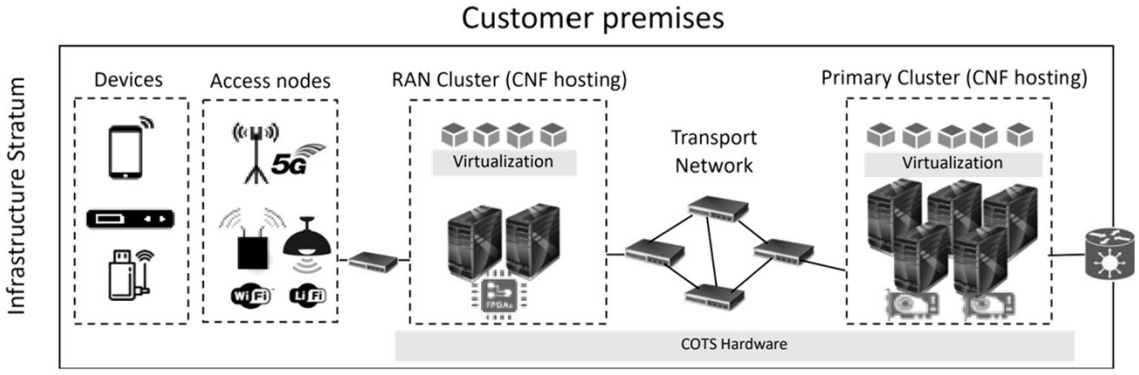
DAY 1: 5G 네트워크 기술

❖ 인프라 계층 (Infrastructure stratum)



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

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DAY 1: 5G 네트워크 기술

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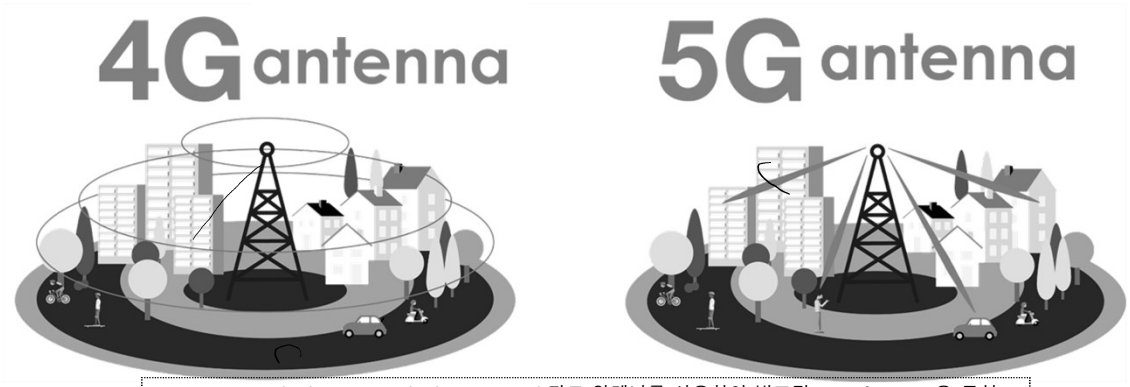
- 5G는 더 큰 대역폭의 스펙트럼을 사용
- 5G 안테나는 빔포밍 기술을 이용하여 동일 주파수를 반복 사용하며 무선 대역폭을 확대



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

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

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DAY 1: 5G 네트워크 기술

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- 5G 네트워크 설계의 발전 방향 고려

무선 스펙트럼:
무선 토폴로지와 셀사이트 관리의 효과와 효율을 위한 투자

클라우드 인프라:
모듈화와 가상 네트워크 기능 지원

AI/ML:
네트워크 복잡성을 관리하고, 필요시 행동을 취함

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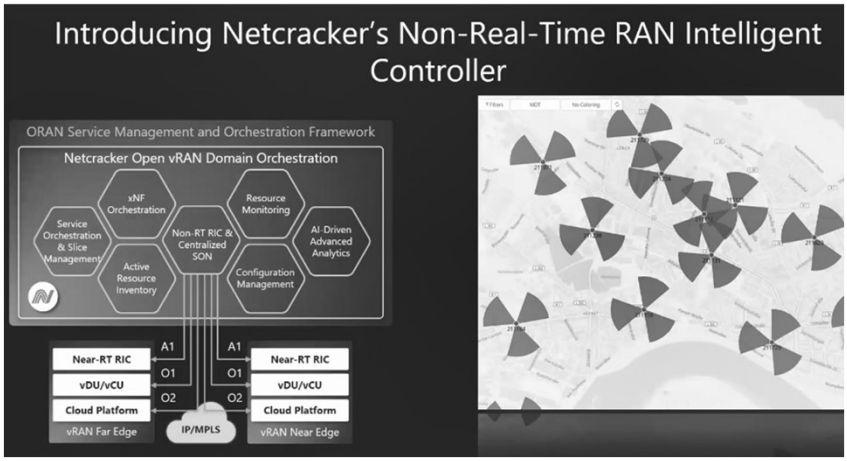
DAY 1: 5G 네트워크 기술

❖ The O-RAN plugfest/PoC in East Asia

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

DAY 1: 5G 네트워크 기술

❖ AI-Driven mMIMO Beam Optimization

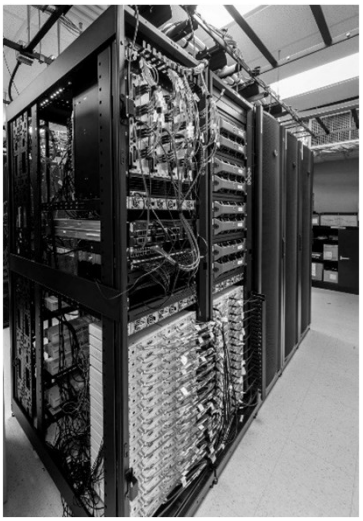


Source: https://stage-o-ran-v2.azurewebsites.net/classic/generation/2021/category/intelligent-ran-control-demonstrations/sub/intelligent-control/110

DAY 1: 5G 네트워크 기술

❖ 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.

Institute for the Wireless Internet of Things at Northeastern

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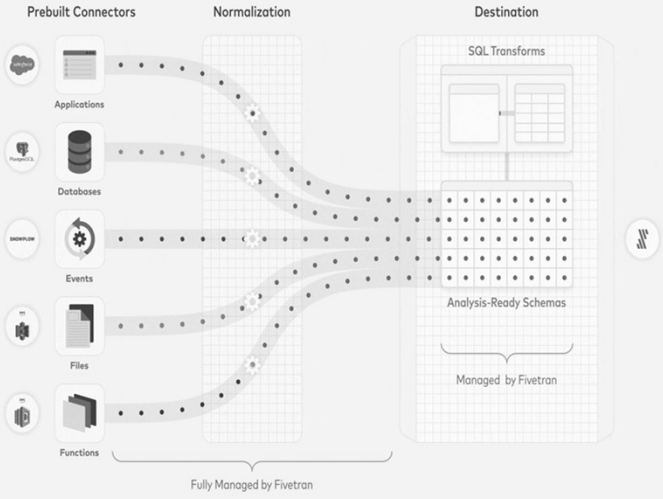
DAY 1: 5G 네트워크 기술

❖ 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

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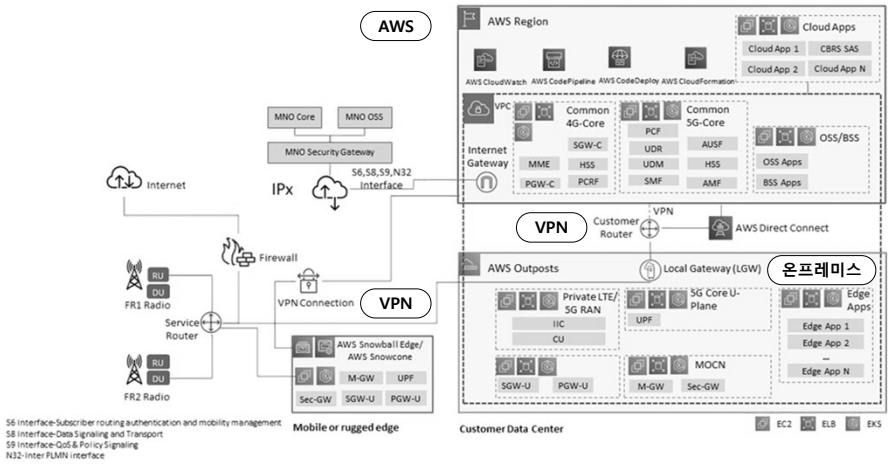
DAY 1: 5G 네트워크 기술

❖ Private 4G/5G on AWS, Deloitte Private Networks Lab Houston.



Source: https://aws.amazon.com/blogs/apn/scalable-mobile-private-4g-and-5g-network-services-on-aws-from-deloitte/

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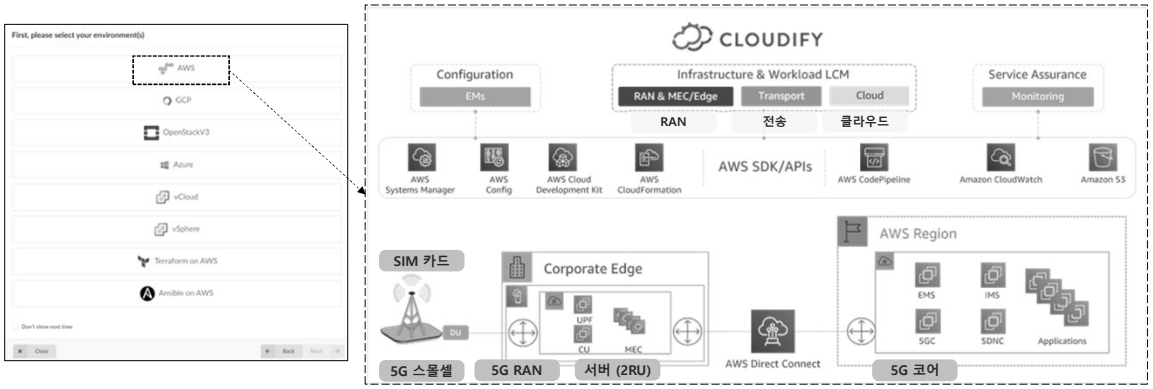
DAY 1: 5G 네트워크 기술

❖ Cloudify: AWS 서비스에 5G 네트워크 슬라이싱 적용

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



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

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DAY 1: 5G 네트워크 기술

❖ Fusion Core - 5G Packet Core @ Azure Marketplace

Source: https://azuremarketplace.microsoft.com/ko-kr/marketplace/apps/metaswitch.fusioncore_0-1-0?tab=Overview

DAY 1: 5G 네트워크 기술

❖ **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 Hakl 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

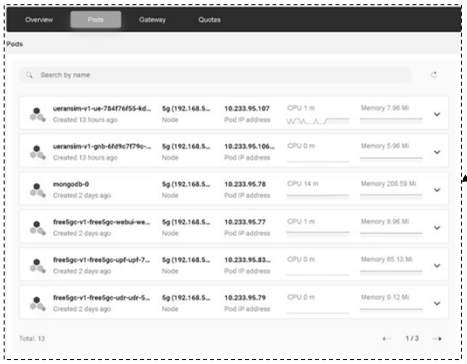
Matt Kapko | Senior Editor, January 7, 2022 8:00 PM

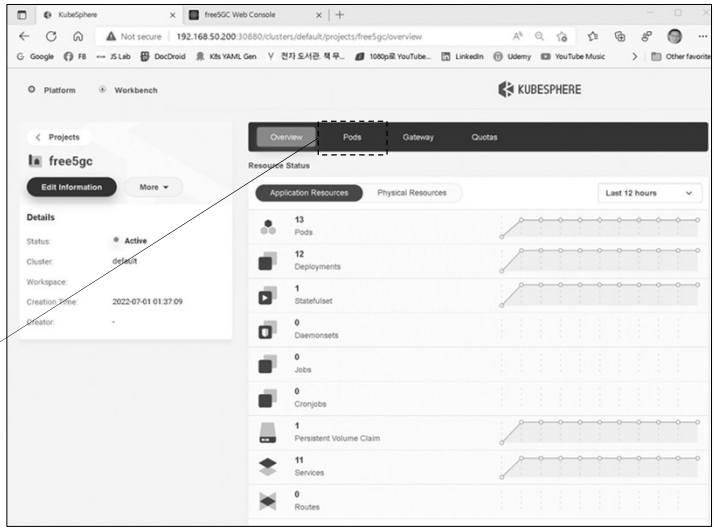
Source: https://www.sdxcentral.com/articles/news/microsoft-teases-5g-cloud-core-progress-post-att-deal/2022/01/

DAY 1: 5G 네트워크 기술

❖ 오픈소스 5G Core/RAN/UE (예)

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





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DAY 1: 5G 네트워크 기술

❖ 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

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DAY 1: 5G 네트워크 기술

❖ 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.

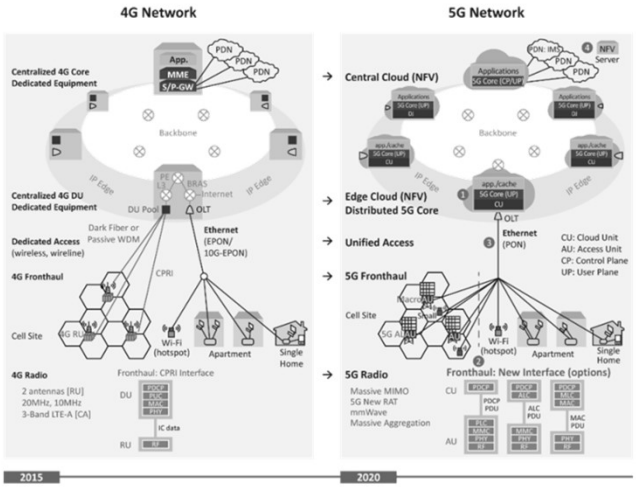
시스템	3G	LTE, 4G	5G
전체 이동 통신 시스템	UMTS	EPS	5GS
무선 접속 기술	UTRA	E-UTRA	NR 또는 E-UTRA
무선 접속망	UTRAN	E-UTRAN	NG-RAN
기지국	Node B	eNodeB	gNodeB

Source: http://terms.tta.or.kr/dictionary/dictionaryView.do?word_seq=167786-3

DAY 1: 5G 네트워크 기술

❖ From 4G to 5G

가상화와 이더넷 기술기반 유선망 확대

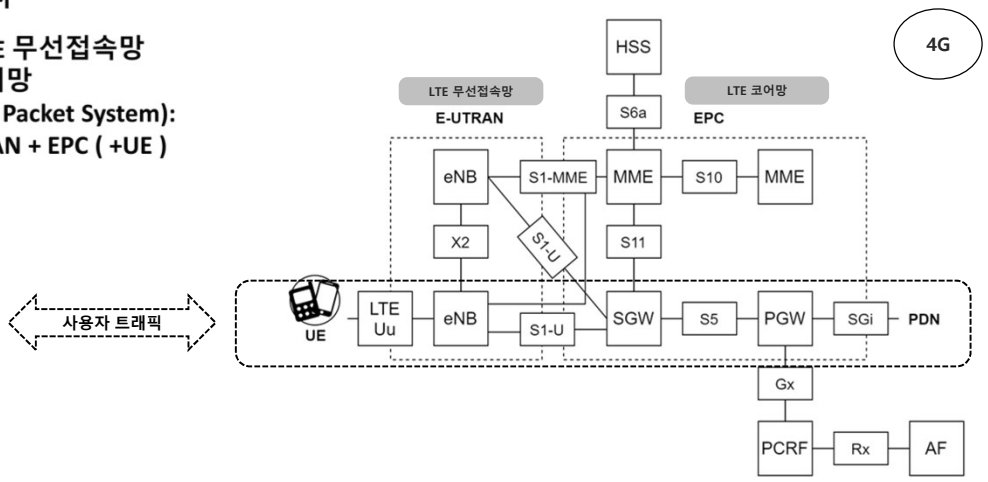


Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

DAY 1: 5G 네트워크 기술

❖ LTE 아키텍처

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



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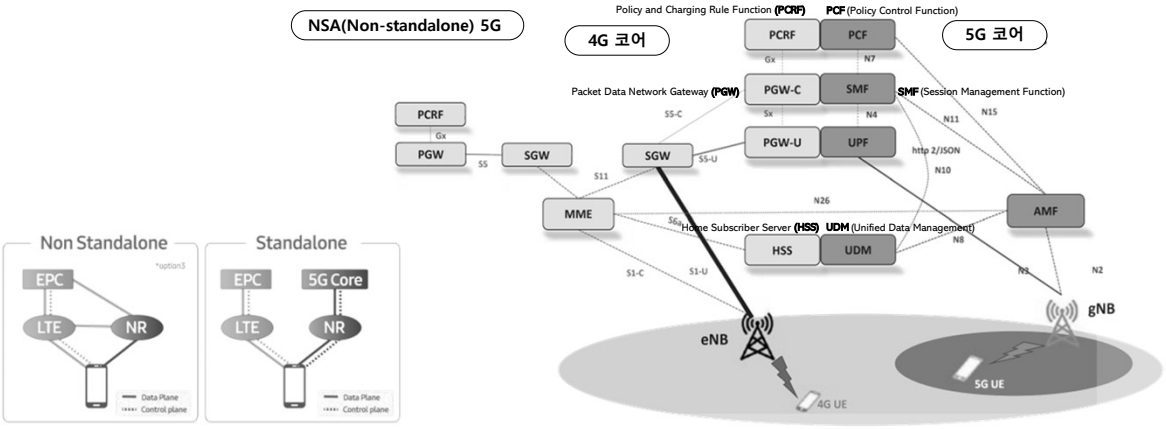
DAY 1: 5G 네트워크 기술

❖ **NSA(Non-standalone) 5G:** 4G LTE architecture with a 5G RAN.

❖ **SA(Standalone) 5G:** 5G RAN and a cloud-native 5G core.



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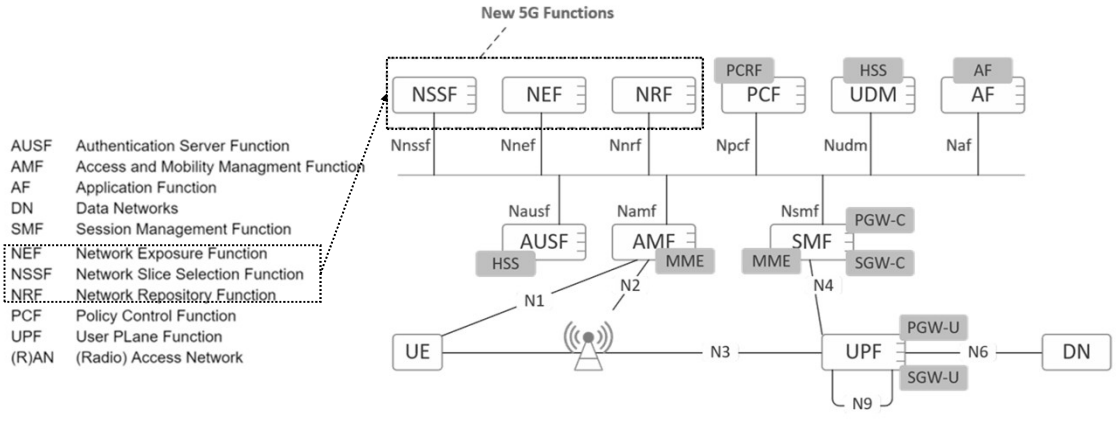
DAY 1: 5G 네트워크 기술

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

• Main functions in 5G SBA



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

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DAY 1: 5G 네트워크 기술

❖ 5G Core NF (Network Function)

UPF(User Plane Function)	기지국/DN간 사용자 패킷 라우팅 및 단말 연결성 제공 솔루션
AMF(Access and Mobility Management Function)	네트워크 접속 및 이동성 관리 솔루션
SMF(Session Management Function)	단말/네트워크간 세션 관리 솔루션
PCF(Policy Control Function)	데이터 패킷 플로우 정책 제어 솔루션
UDM(Unified Data Management)	사용자 정보 및 정책 관리 솔루션
UDR(Unified Data Repository)	사용자 정보 및 정책 통합 저장 솔루션
AUSF(Authentication Server Function)	네트워크/사용자 상호 인증정보 관리 솔루션
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

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

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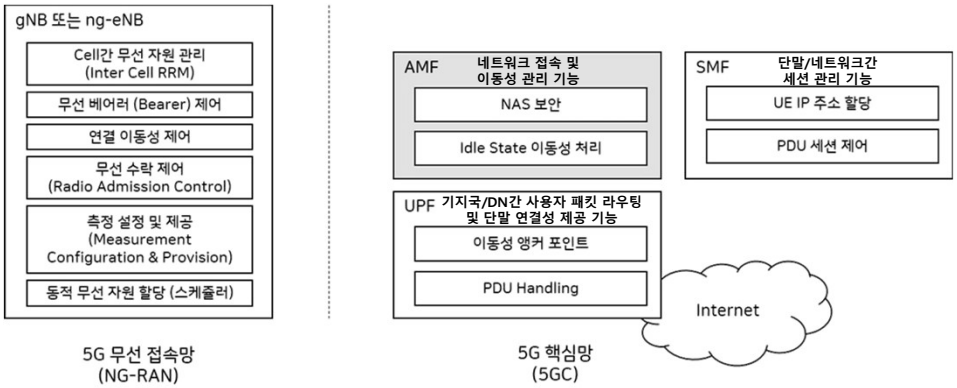
DAY 1: 5G 네트워크 기술

❖ 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

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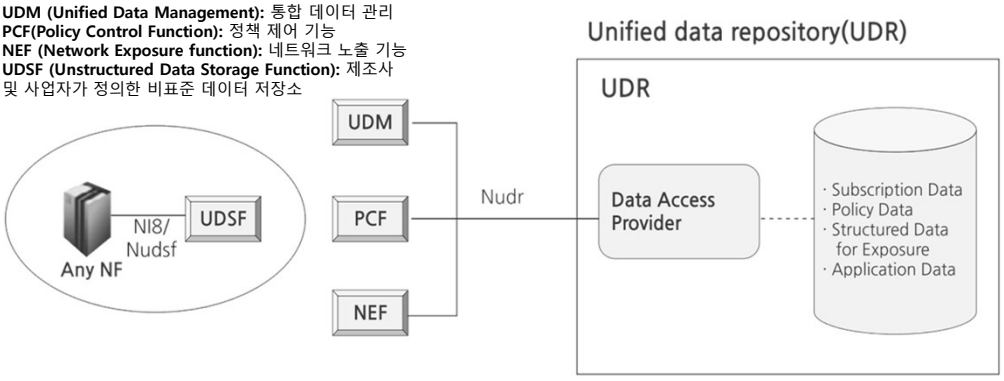
DAY 1: 5G 네트워크 기술

❖ 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

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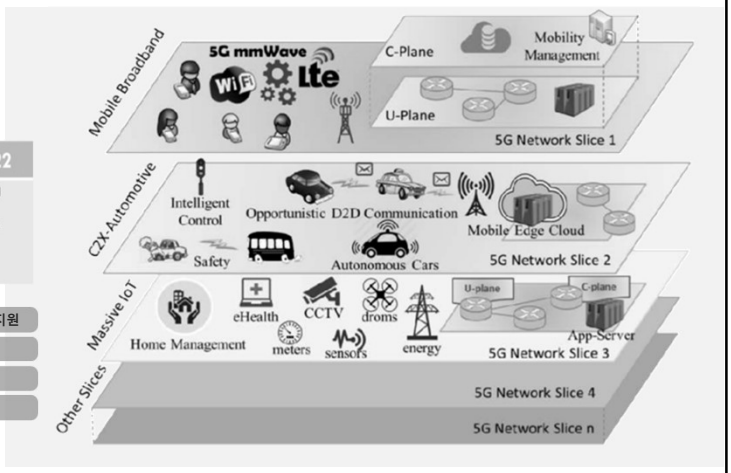
DAY 1: 5G 네트워크 기술

❖ Basic slicing of 5G core network

- Wi-Fi, LTE, 5G

Release 15 - 2019	Release 16 - 2020	Release 17 -2022
• First NR ("New Radio") release. • 5G Vehicle-to-x service • Service Based Architecture (SBA)	• The 5G System - Phase 2 • Industrial IoT • URLLC enhancements • 5G efficiency including Dynamic Spectrum Sharing (DSS)	• Support for non-terrestrial networks • Unmanned Aerial Systems • RAN Slicing • Edge Computing

- 비지상네트워크 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

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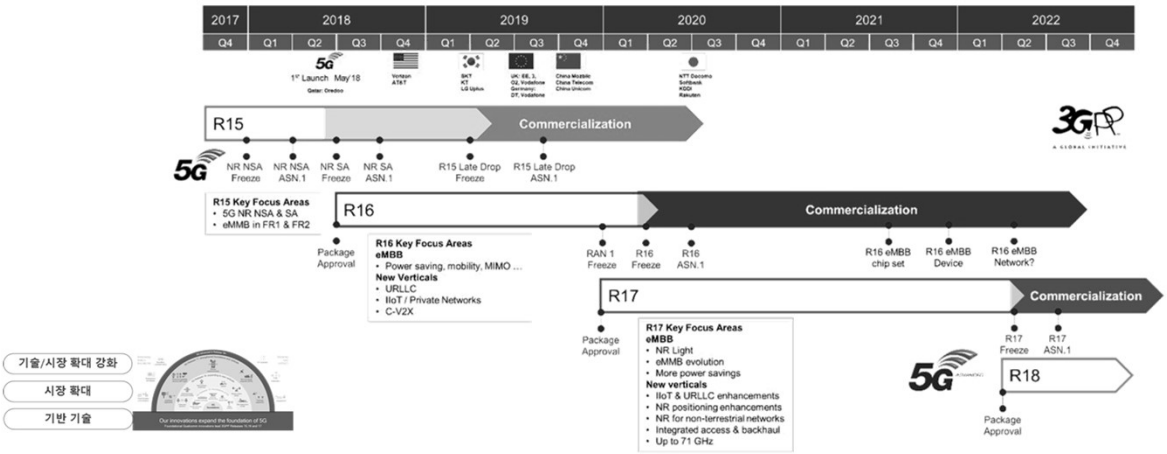
DAY 1: 5G 네트워크 기술

❖ 3GPP standards timeline



Source: https://www.ednasia.com/what-are-the-standards-for-5g-private-networks/

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DAY 1: 5G 네트워크 기술

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❖ 3GPP - Rel. 15

- MIMO
- MRDC
- DSS
- Coverage
- Others

MRDC(Multi-RAT Dual Connectivity)

DSS (Dynamic Spectrum Sharing)
동적 스펙트럼 공유

MIMO Enhancements

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

MRDC

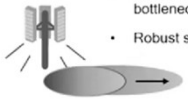
- Quickly turnoff unneeded radio on the device
- Improve battery life

DSS

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

5G NR 기술 기반

Coverage Extension



- Remove signaling bottleneck
- Robust singalling

Many Others

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

Source: Tantra Analyst

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DAY 1: 5G 네트워크 기술

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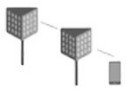
❖ 3GPP - Rel. 16

- 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

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DAY 1: 5G 네트워크 기술

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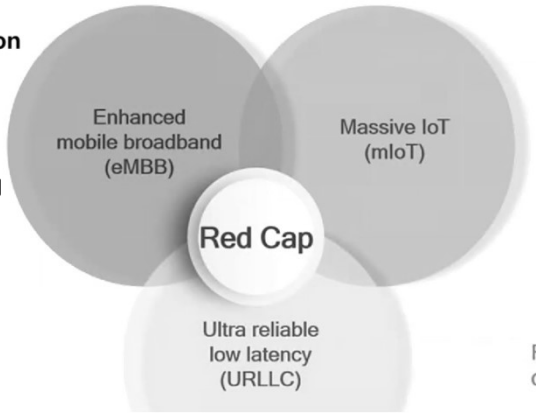
❖ 3GPP - Rel. 17 (Red Cap)

- 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

JS Lab

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DAY 1: 5G 네트워크 기술

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❖ 3GPP - Rel. 17 (New Concepts)

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

지속적 확대 / 개선

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

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

JS Lab

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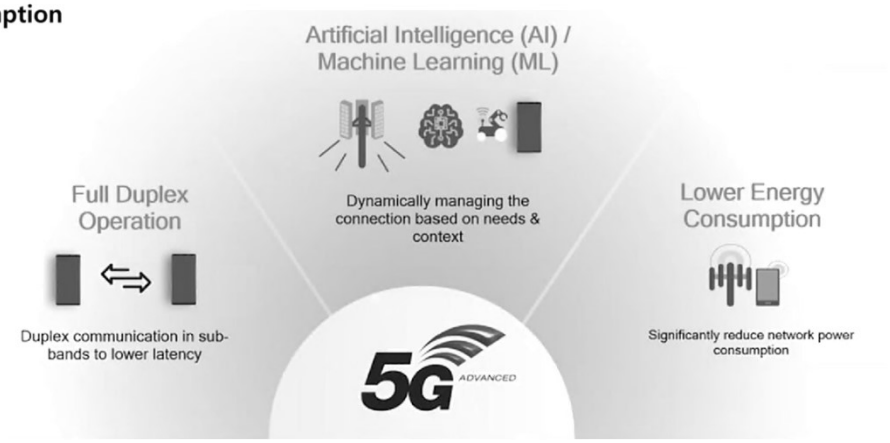
DAY 1: 5G 네트워크 기술

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

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

비지상
AI/ML
사이드링크
Etc.



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DAY 1: 5G 네트워크 기술

❖ Air Interface

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

Non-Access Stratum (NAS)

Radio Resource Control (RRC)

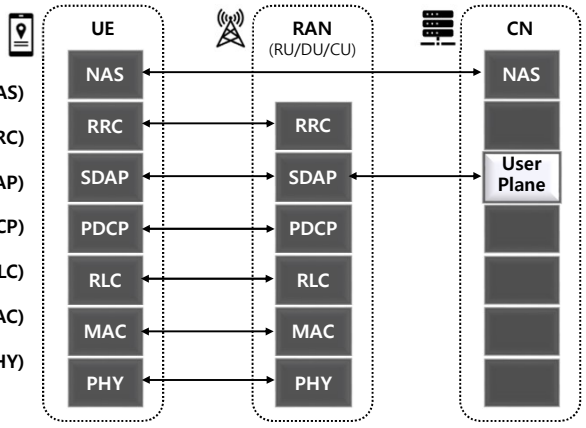
Service Data Adaptation Protocol (SDAP)

Packet Data Convergence Protocol (PDCP)

Radio Link Control (RLC)

Medium Access Control (MAC)

Physical (PHY)



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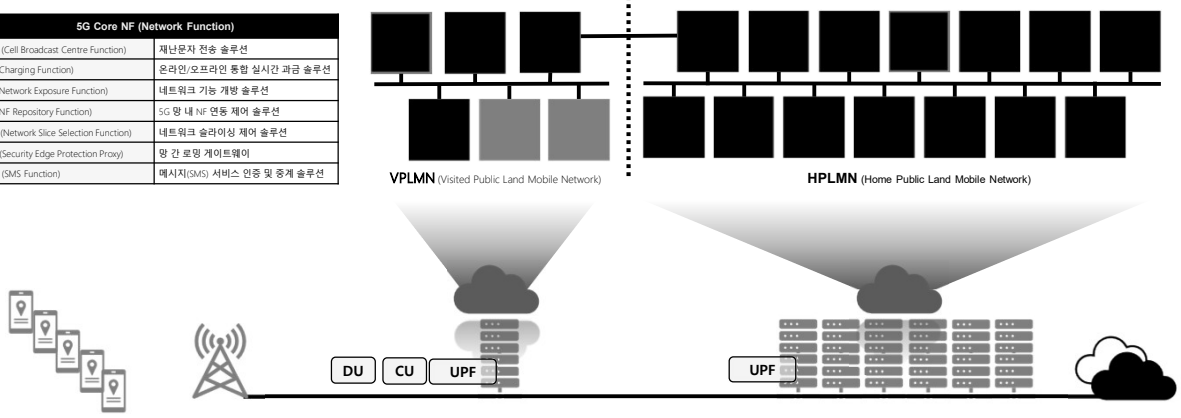
DAY 1: 5G 네트워크 기술

❖ 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



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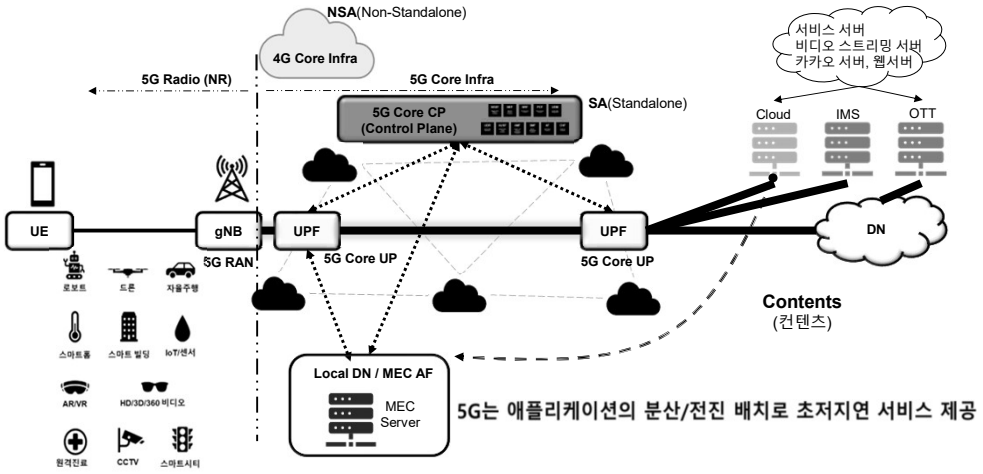
DAY 1: 5G 네트워크 기술

❖ 에지의 분산 클라우드 (Distributed cloud with autonomous edge)



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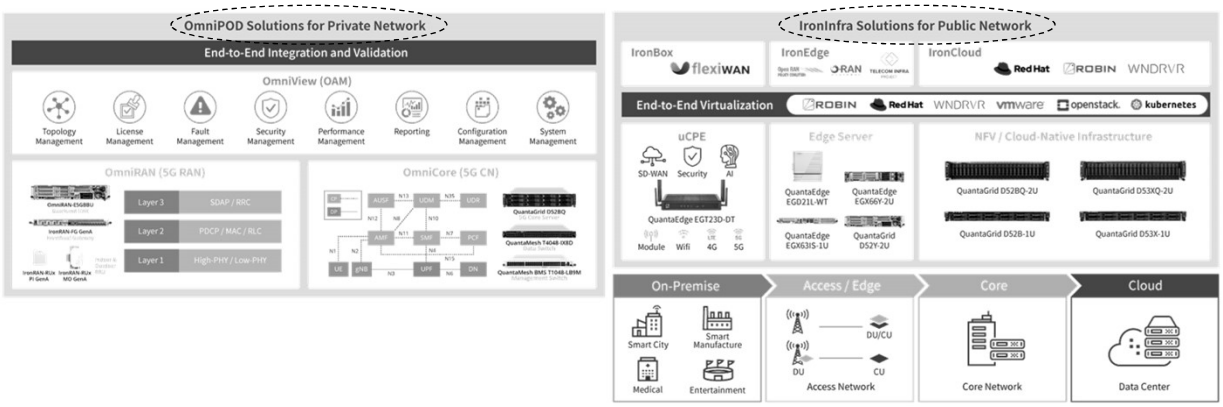
DAY 1: 5G 네트워크 기술

❖ 제조사 (예): QCT



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

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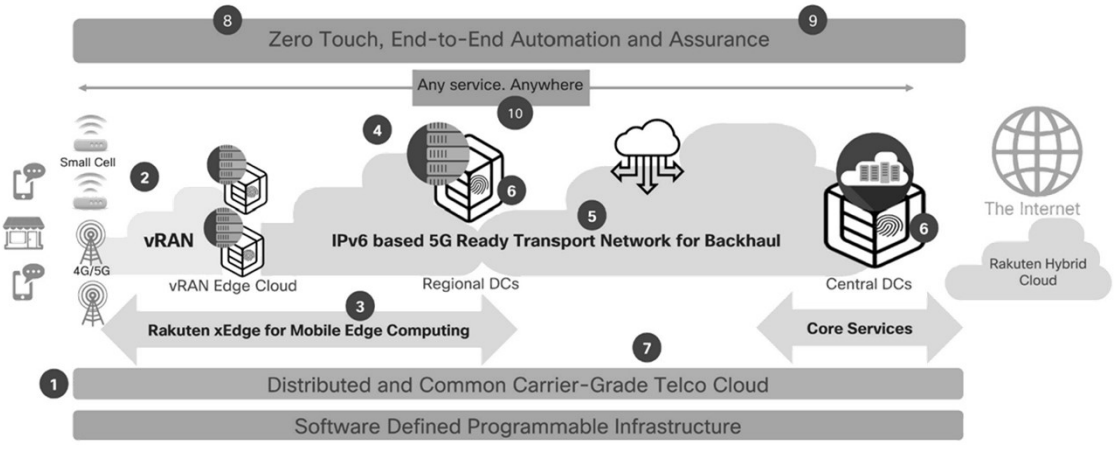
DAY 1: 5G 네트워크 기술

❖ 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

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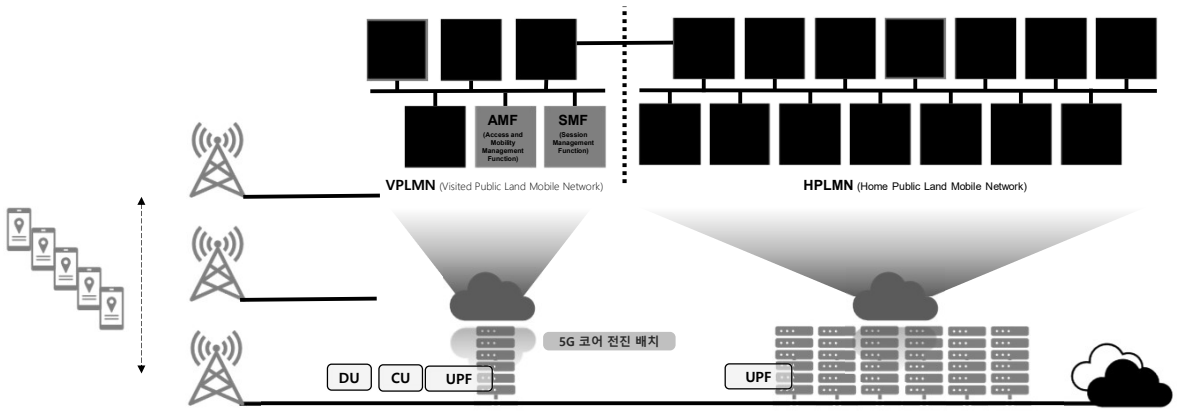
DAY 1: 5G 네트워크 기술

❖ 5G 코어 기능의 분산 배포



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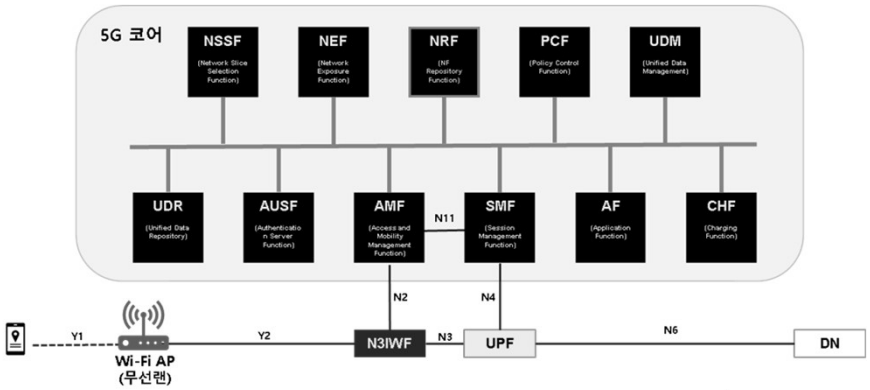
II. 5G EN-DC ARCHITECTURE

❖ non-3GPP

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



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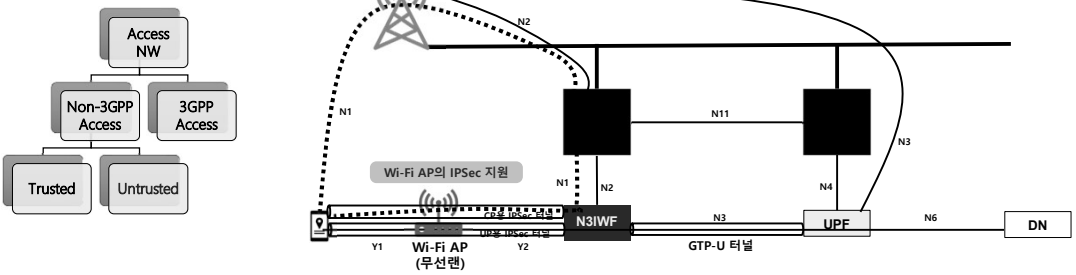
DAY 1: 5G 네트워크 기술

❖ non-3GPP

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

○ CP용 IPSec 터널, UP용 IPSec 터널, GTP-U 터널



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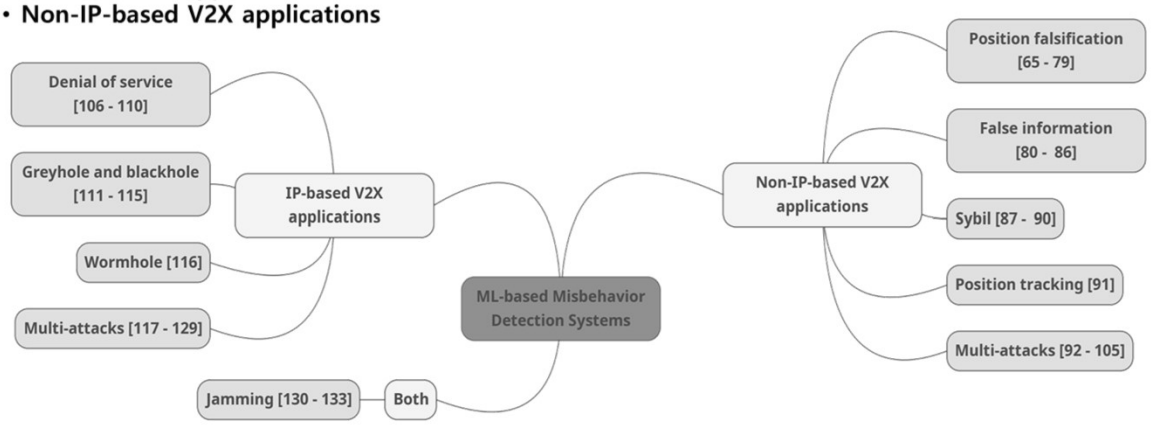
DAY 1: 5G 네트워크 기술

❖ 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

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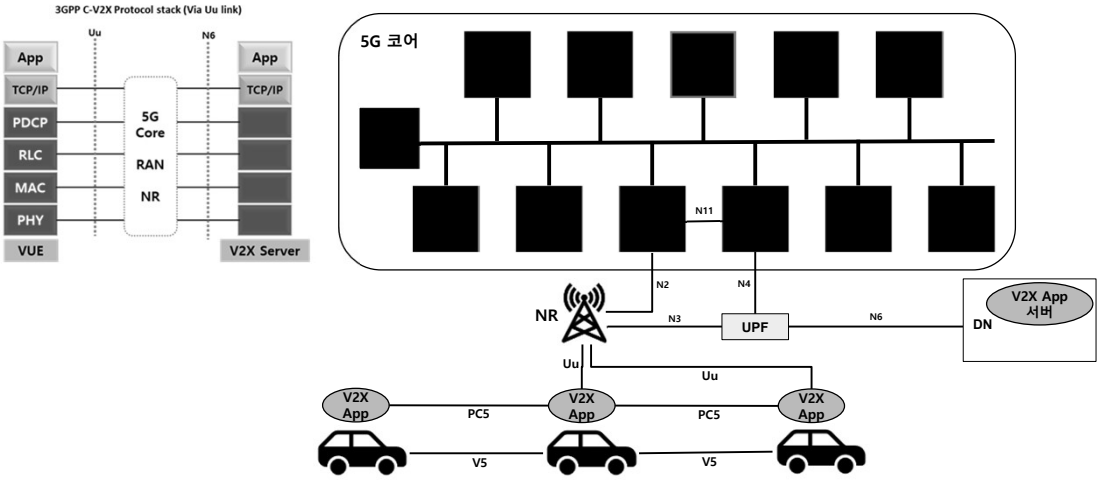
DAY 1: 5G 네트워크 기술

❖ 5G-V2X Architecture



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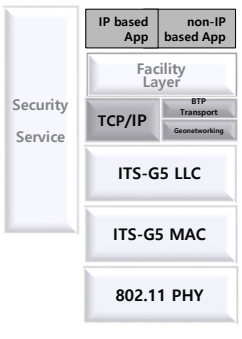
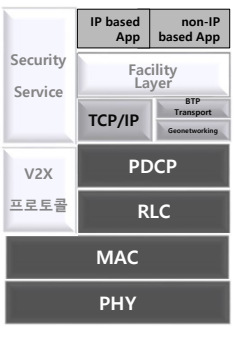
DAY 1: 5G 네트워크 기술

❖ V2X Protocol Stacks

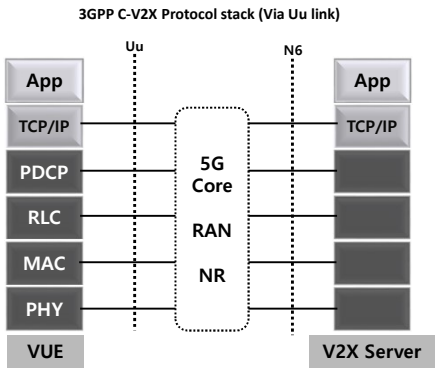
- ETSI ITS-G5 Protocol stack
- 3GPP C-V2X Protocol stack
- 3GPP C-V2X Protocol stack (Via Uu link)



ETSI ITS-G5 Protocol stack



3GPP C-V2X Protocol stack



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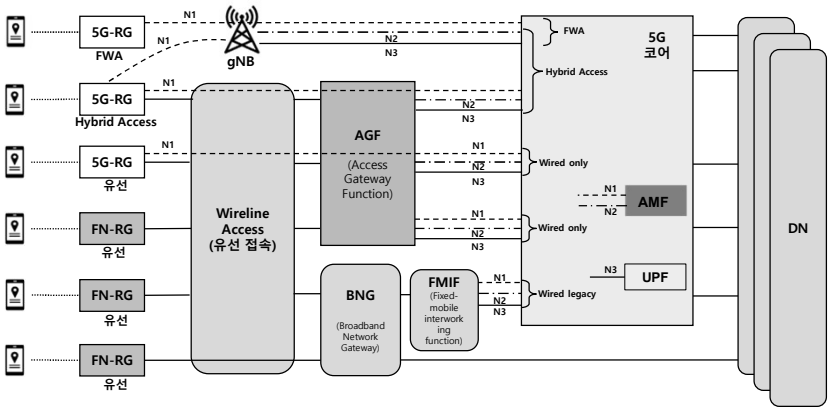
DAY 1: 5G 네트워크 기술

❖ **FMC(Fixed Mobile Convergence)**

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



DAY 1: 5G 네트워크 기술

❖ **non-3GPP Access Network 비교**

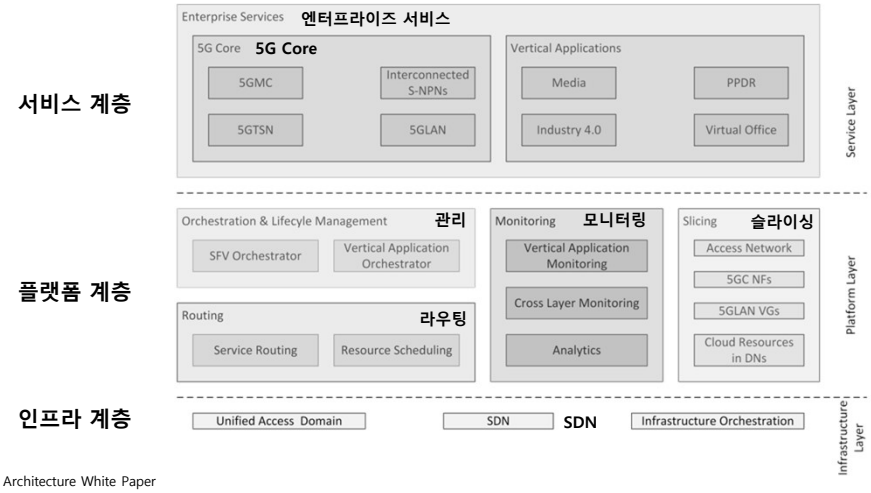
- **COMPARISON BETWEEN NON-3GPP ACCESS NETWORKS ACCORDING TO 3GPP (REL-15/REL-16)**

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 기술

❖ 5G 하이레벨 시스템 구성 (예): FUDGE-5G



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

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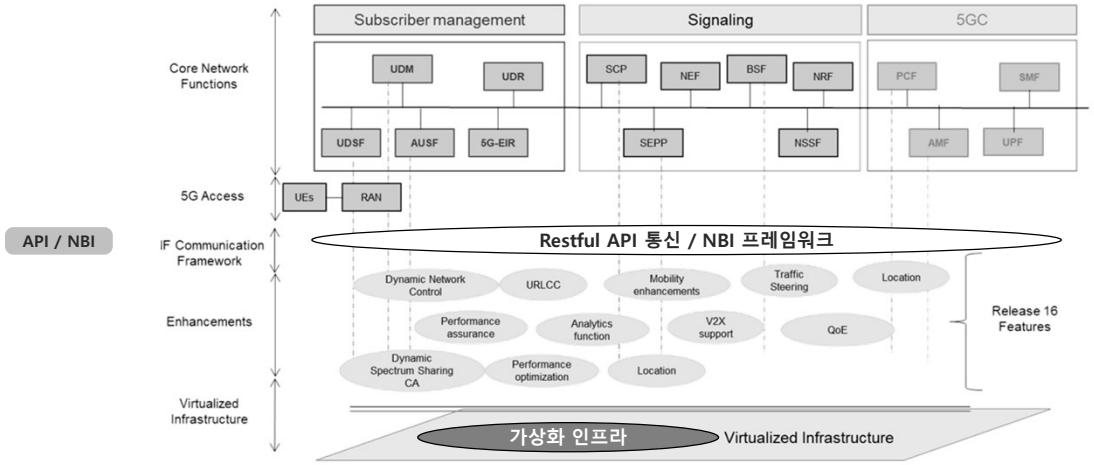
DAY 1: 5G 네트워크 기술

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



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

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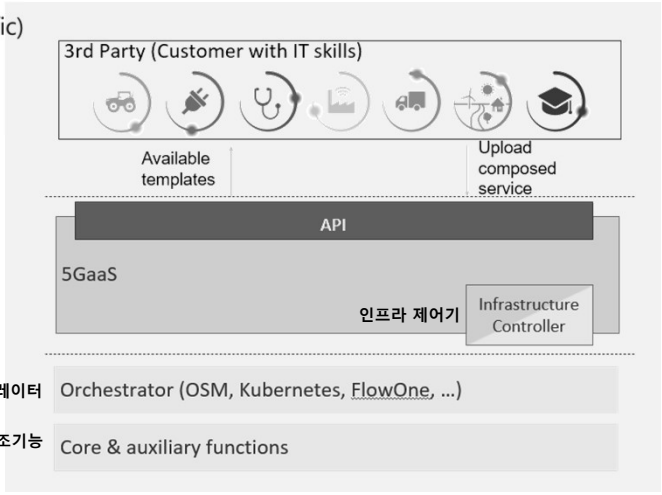
DAY 1: 5G 네트워크 기술

❖ 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

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DAY 1: 5G 네트워크 기술

❖ 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
#(Core + 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 parametes
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
deployNEF: 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: 8Gi
    mountPath: /bitnami/mongodb/data/db/
  service:
    name: mongodb
    type: ClusterIP
    port: 27017
    nodePort: "30017"
```

Note: https://helm.sh/docs/intro/using_helm/

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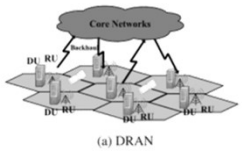
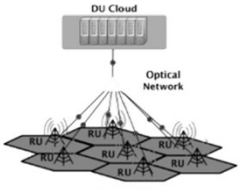
DAY 1: 5G 네트워크 기술

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

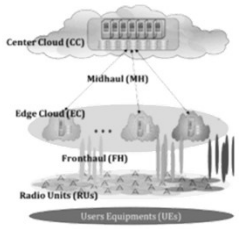
- **DRAN**
- **CRAN**
- **H-CRAN**



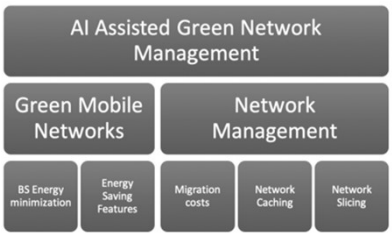
(a) DRAN



(b) CRAN



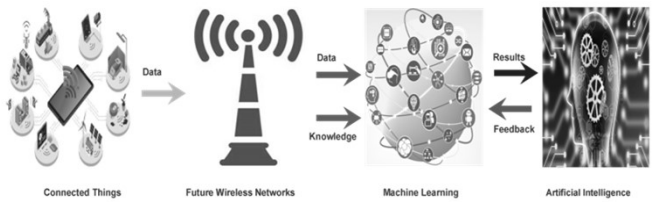
(c) H-CRAN



Source: http://kth.diva-portal.org/smash/get/diva2:1626735/FULLTEXT01.pdf?fbclid=IwAR1F1GlV3bU_YONZzxElLtb4kp_Y7t70VczSb_0abIVqJZxt2ErbJ60UuAg

DAY 1: 5G 네트워크 기술

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

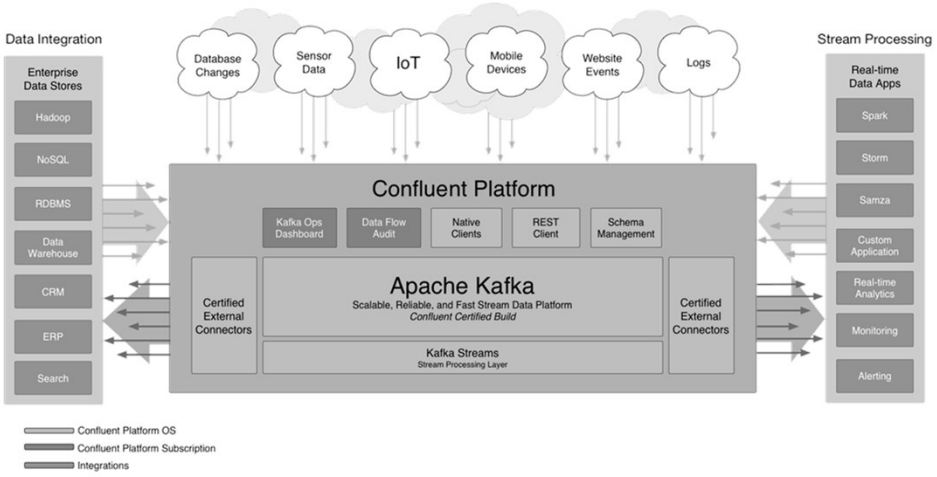


Author References	적용 분야 Key Contribution	적용 방법 ML Applied	Network Participants Component		5G Network Application Parameter				
			RAN	Core	LB	SDN	RAN	RA	SEC
Alave et al. [68]	Network traffic prediction	LSTM and DNN	✓	✓	*	✓	✓	✓	X
Bega et al. [15]	Network slice admission control algorithm	Machine Learning and Deep Learing	✓	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	*	*

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

DAY 1: 5G 네트워크 기술

❖ **Stream Processing (예: Confluent Platform)**



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

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DAY 1: 5G 네트워크 기술

❖ **KOREN 기반 5G Testbeds**

• **5G 오픈테스트랩 개요**

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DAY 1: 5G 네트워크 기술

❖ KOREN 기반 5G Testbeds

• 공인인증 테스트 지원

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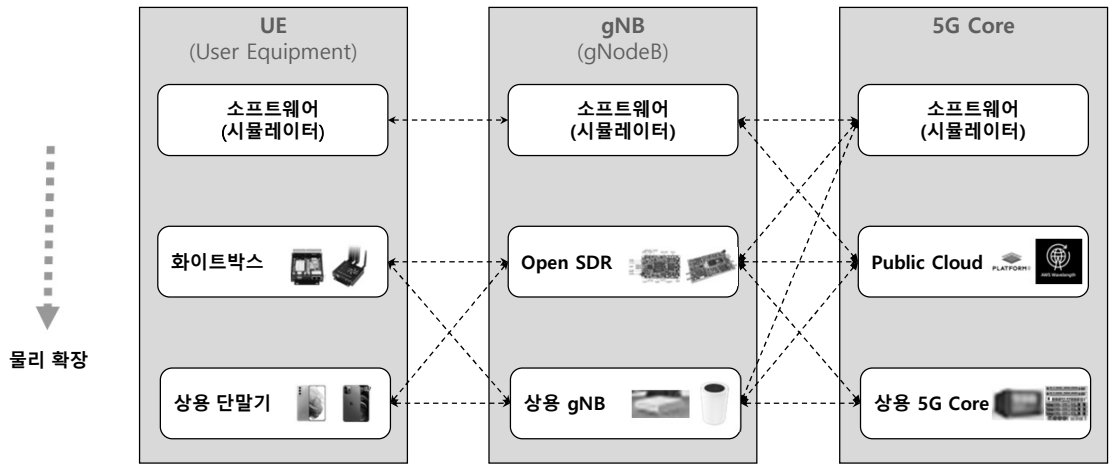
DAY 1: 5G 네트워크 기술

❖ 5G 네트워크 인프라 구성 (시험/개발/구축)



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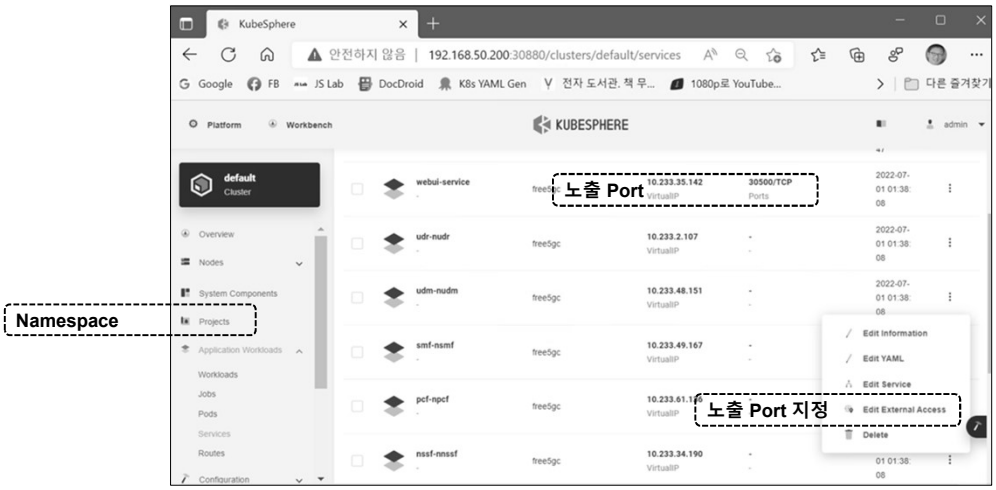
DAY 1: 5G 네트워크 기술

❖ 5G 네트워크 인프라 구성 (시험/개발/구축 기능 연계)



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DAY 1: 5G 네트워크 기술

❖ 5G 코어 오픈소스 비교 (Conformance tests)

- free5GC
- Open5GS
- OAI

Procedures on testing	Protocols	Messages	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

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DAY 1: 5G 네트워크 기술

❖ 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 기술

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

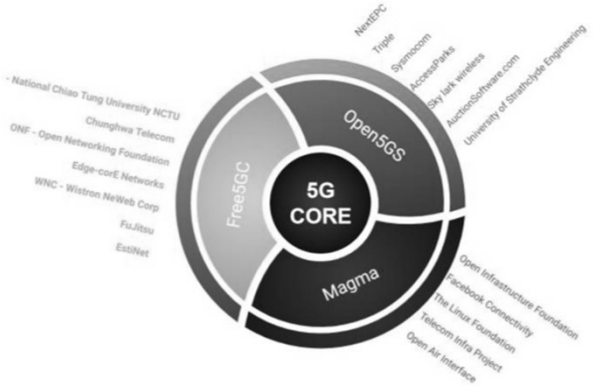
❖ 'Analysis for Comparison of Framework for 5G Core Implementation

- Magma
- Open5GS
- Free5GC

TABLE I. ELEMENTS NECESSARY TO DEPLOY

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

K8s 시연 구성



Major supporters of Core 5G development.

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 기술

❖ 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 분배 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	• 구성 설정은 Yaml 파일을 직접 편집합니다. 필요, 편집 부분을 많이 이해하기 어렵다. • 알람은 시스템 로그 파일에서 확인	• 구성 설정은 Yaml 파일을 편집해야합니다. 요 편집 부분을 많이 이해하기 어렵다. • 알람은 시스템 로그 파일보다 확실합니다. 인정	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

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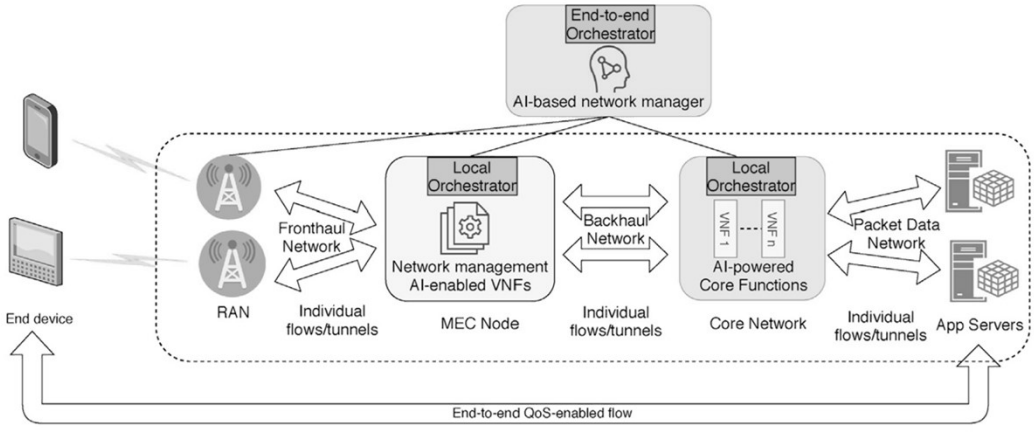
DAY 1: 5G 네트워크 기술

❖ 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

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DAY 1: 5G 네트워크 기술

❖ News: Google, Linux Foundation Launch Nephio to Automate 5G

- 네피오 프로젝트: The Nephio project is designed to provide Kubernetes-based cloud-native intent automation and automation templates to make it easier for telecom operators to deploy and manage multi-vendor cloud infrastructure and network functions across large-scale edge deployments. It sits on top of a Kubernetes substrate either directly controlled from an operator or a hyperscaler-based platform like Google Config Connector, Amazon Web Services (AWS) Controllers for Kubernetes, and Azure Service Operator

Dan Meyer | Executive EditorApril 13, 2022 4:00 AM

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

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DAY 1: 5G 네트워크 기술

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

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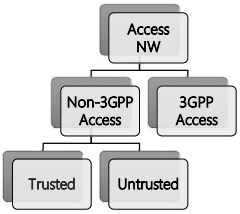
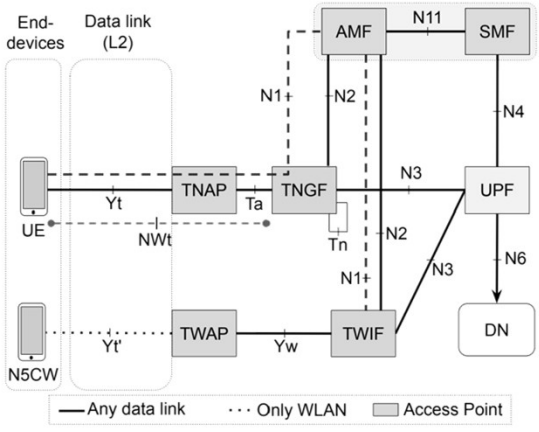
DAY 1: BACKUP

❖ **trusted non-3GPP**

• **Connection options to trusted non-3GPP access networks.**





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

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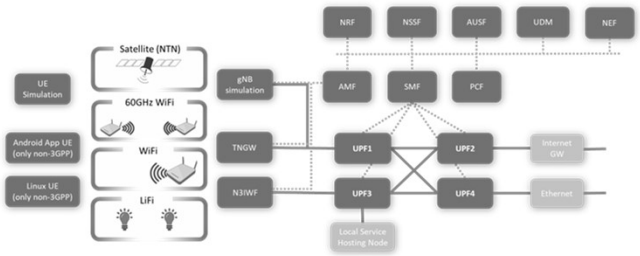
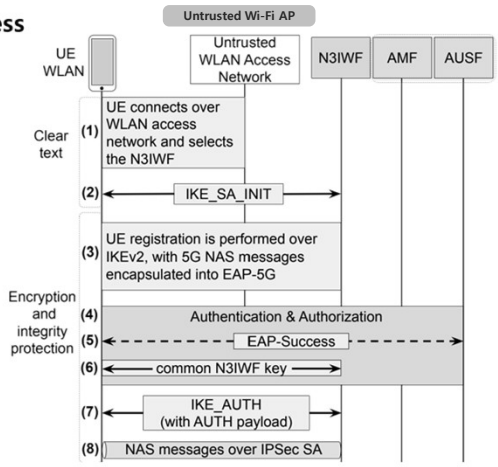
DAY 1: BACKUP

❖ **Untrusted Access 시그널링 수립**

• **Signaling IPSec SA establishment over untrusted access**





Source: https://www.open5gcore.org/578eda8af4602d2c

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