5G 네트워크

(Day 2. Enhanced Mobile Broadband)

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)

➢ Day 2: Enhanced Mobile Broadband

- Review Day 1
- NR 과 Access Network
- 5G Access Network 구조
- 5G Spectrum 기술
- 5G Network Slicing

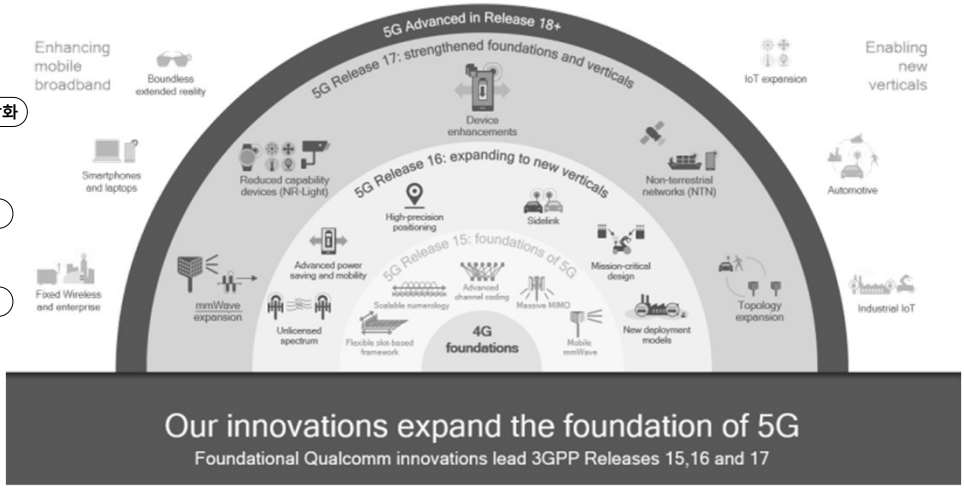
DAY 2: ENHANCED MOBILE BROADBAND

❖ **3GPP standards 3GPP Rel, 15, 16, 17** (기술과 시장 확대 강화)

Rel. 17 기술/시장 확대 강화

Rel. 16 시장 확대

Rel 15. 기반 기술



Source: 퀄컴

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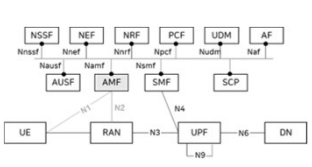
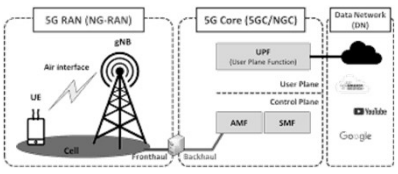
❖ **5세대 이동통신 핵심망, 五世代移動通信核心網, 5th Generation Core Network, 5GC**

- **AMF** (Access and Mobility management Function)**: 접속과 이동성 관리 기능**
- **SMF** (Session Management Function)**: 세션 관리 기능**
- **UPF** (User Plane Function)**: 사용자 평면 기능**
- **PCF** (Policy Control Function)**: 정책 제어 기능**
- **AUSF** (Authentication Server Function)**: 인증 서버 기능**
- **UDM** (Unified Data Management)**: 통합 데이터 관리**
- **AF** (Application Function)**: 응용 기능**
- **NEF** (Network Exposure function)**: 네트워크 노출 기능**
- **NRF** (Network Repository Function)**: 네트워크 저장소 기능**
- **NSSF** (Network Slice Selection Function)**: 네트워크 슬라이스 선택 기능**





https://jb-story.tistory.com/346

Source: http://terms.tta.or.kr/dictionary/dictionaryView.do?word_seq=171377-2

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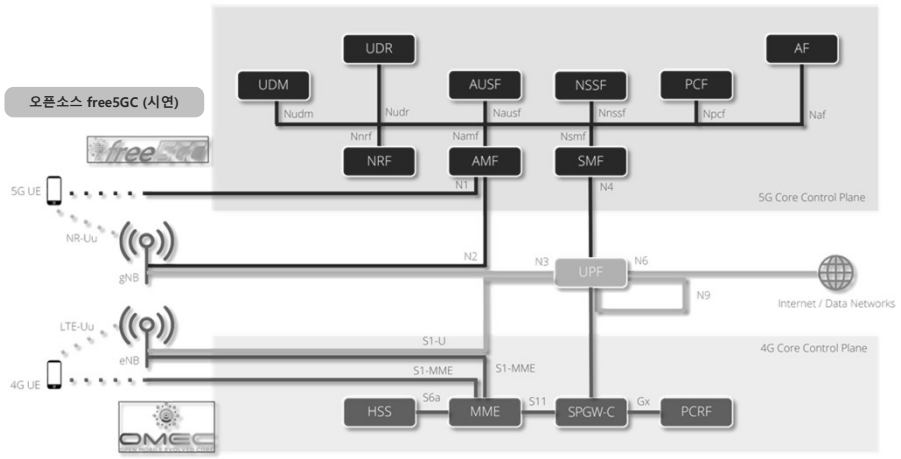
❖ SD-Core supports 5G SA, 5G NSA (option 3x) and LTE



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❖ 엔터프라이즈의 개선 요구 (Key Concerns for the Enterprise)

- WiFi와 고정의 한계
- 보안과 데이터 프라이버시
- 더 높은 대역폭
- 효율적인 운영
- 커넥티드 기기

Wi-Fi & Fixed Limitations

Enhanced reliability and mobility compared to traditional networks.

Security & Data Privacy

More control and visibility of data with end-to-end encryption.

More Bandwidth

Exponential increases in data processing requires speed and performance for automation.

Operational Efficiency

Support the growing ecosystem of IoT sensors and connected applications.

Connected Devices

Support for digital transformation and convergence of IT & OT.

Source: Analysys Mason
Private LTE/5G networks: worldwide trends and forecasts 2021–2026

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❖ 엔터프라이즈 기업의 기술 비교 (예): **Private LTE vs WiFi vs 5G** (VMware 예)

		Private LTE	Wi-Fi 6	5G
환경	Environment	• All environments • Mines • Construction Site • Sites where Public LTE does not exist	• Office environments • Homes • Shopping Malls • Transportation Hubs	• All environments including industrial environments 산업 환경을 위한 모든 환경
가용성	Availability	• Available now	• Wi-Fi 6 certification finalized in Q3 2019	• Rel 16 to be finalized in June 2020 • Commercial availability 2021 현재 사용 가능
속도	Speed	• Up to 1 Gbps	• Up to 9.6 Gbps	• Up to 10 Gbps 최대 10 Gbps
밀도	Density	• 100,000 connections per KM	• Designed for densely digitally populated homes and offices	• 1M connections per KM 제곱킬로미터당 1M
모빌리티	Mobility	• Roaming from private to public LTE networks	• Designed for fixed locations	• Roaming from private to public LTE networks Private Public 로밍
지연/신뢰성	Latency and Reliability	• 40-50 milliseconds	• >100 milliseconds but may not be able to guarantee low latency as load increases	• Ultrareliable low latency • Sub millisecond latency • 99.9999% reliability 초저지연, 99.9999% 신뢰
주파수 범위	Frequency Ranges	• Licensed and unlicensed spectrum • CBRS (3.5 GHz) in US	• 2.4 Ghz and 5 Ghz	• Licensed and unlicensed spectrum • 600 MHz to mmWave (24-29 Ghz and 37-43 Ghz) 면허/비면허 mmWAVE

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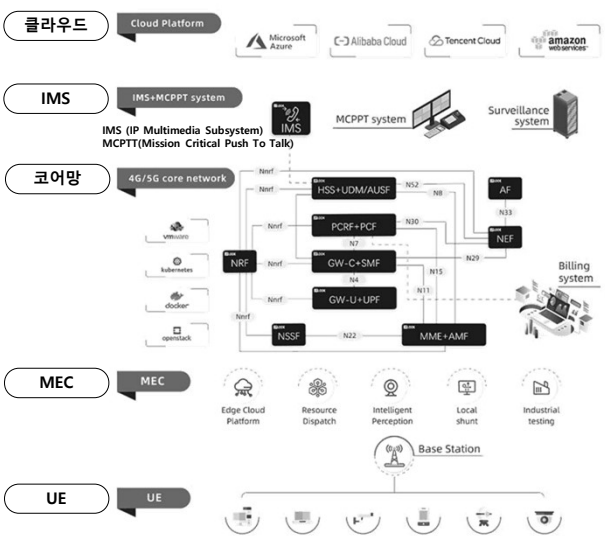
❖ **Deploy private 5G network on cloud(예)**

- **Cloud Platform**
- **IMS-MCPPT system**
- **4G/5G core network**
- **MEC** (Mobile Edge Computing)
- **UE** (User Equipment)



Source: https://www.iplook.com/info/deploy-private-5g-network-on-cloud-i00173i1.html

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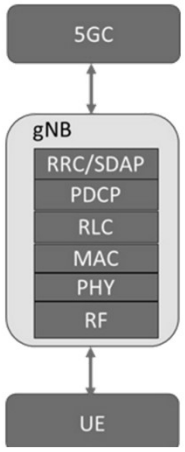
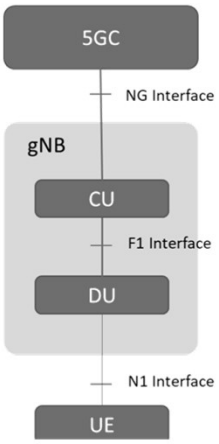
❖ **RAN 구조의 변화 (New C-RAN/Fronthaul)**





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

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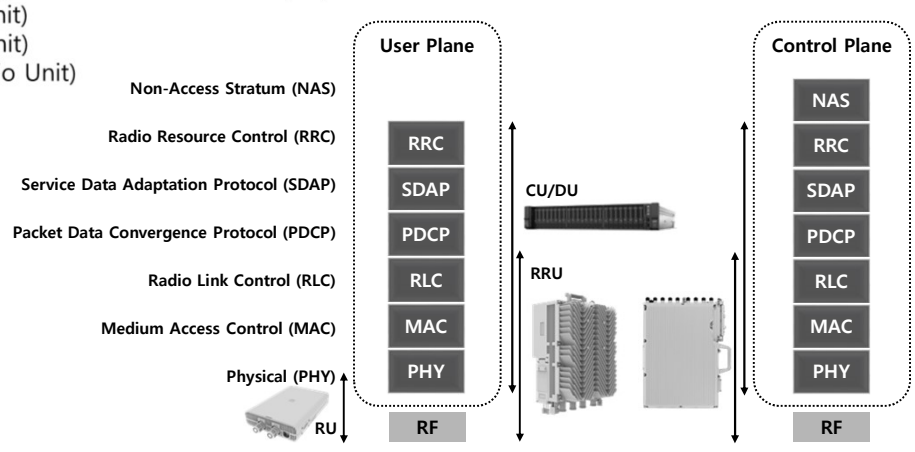
❖ **Air Interface**

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



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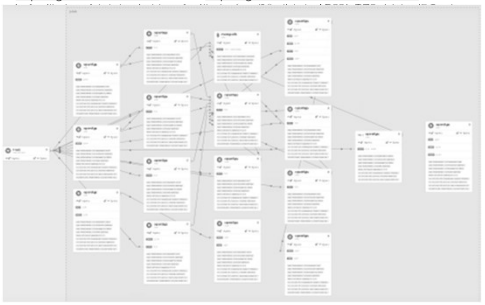
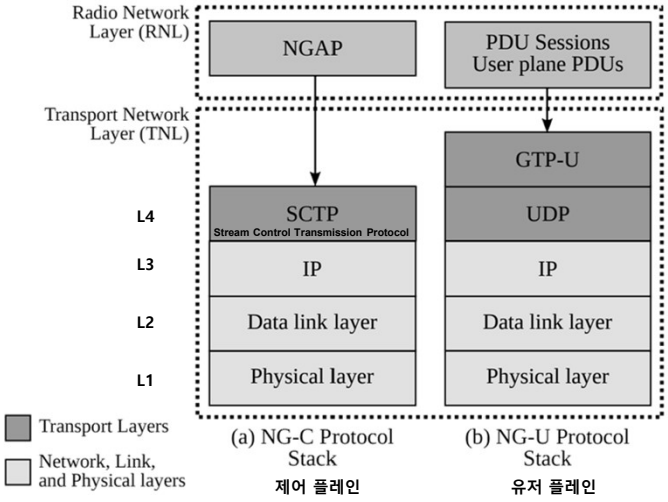
❖ NG-C 와 NG-U 프로토콜 스택

- 제어 플레인 (NG-C)
- 유저 플레인 (NG-U)

https://github.com/loxilb- https://github.com/loxilb-io/loxilbdocs



UE ←→ gNB ←→ UPF ←→ DN



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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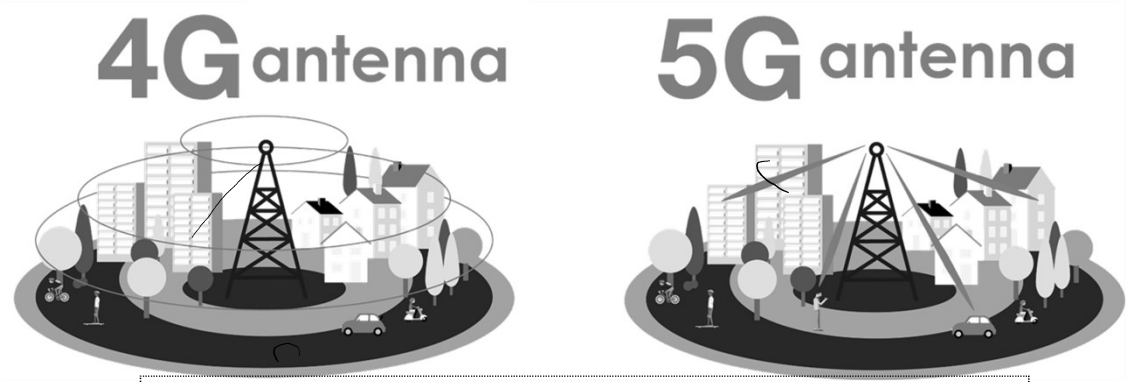
❖ 5G는 더 큰 대역폭의 스펙트럼을 사용

❖ 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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❖ 세대별 주파수 이용현황

구분	주파수(대역폭)	대역폭 합계
2G	800MHz(10MHz), 1.8GHz(20MHz)	30 MHz
3G	2.1GHz(40MHz)	40 MHz
4G	800MHz(50MHz), 900MHz(20MHz), 1.8GHz(90MHz), 2.1GHz(80MHz), 2.6GHz(100MHz)	340 MHz
5G	3.5GHz(280MHz), 28GHz(2400MHz)	2,680 MHz

- 낮은 대역의 주파수 일수록 장애물의 영향을 적게 받으며, 대역폭이 넓을수록 빠른 전송속도의 구현
- 낮은 대역의 주파수는 이미 포화상태이므로 5G는 고주파 및 초고주파 영역 활용을 위한 기술 개발

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❖ 5G 표준과 Market의 Radio 환경 변화/발전

주파수	Sub 6GHz		Above 6GHz		
대역 / 통산사	<3GHz	3~5 GHz	6~24 GHz	24~30 GHz	30~40 GHz
SKT		3.6~3.7 GHz (100MHz)		28.1~29.0 GHz (800MHz)	
KT		3.5~3.6 GHz (100MHz)		26.5~27.3 GHz (800MHz)	
LGU+		3.42~3.5 GHz (80MHz)		27.3~28.1 GHz (800MHz)	

동시 지원 가능
- 5G NR (100MHz) 1.5 Gbps
- 4G LTE (145MHz) 1.2 Gbps

- Frequency range 1 (FR1): 410–7125 MHz.
- Frequency range 2 (FR2): 24.25–52.6 GHz.

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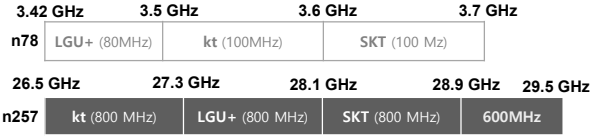
❖ FR1: n78 (3.3GHz~3.8GHz)

❖ FR2: n257 (26.5GHz~29.5GHz)

Frequency range	Carrier bandwidth (MHz)
FR1	5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100
FR2	50, 100, 200, 400

NR Band	Uplink and Downlink Range (MHz)	Duplex Mode	Main Region(s)
n257	26,500–29,500	TDD	Asia, Americas (global)
n258	24,250–27,500	TDD	Europe, Asia (global)
n259	37,000–40,000	TDD	US (global)



re-farming carriers from LTE to NR

DSS(Dynamic spectrum sharing)

	NR Band	Uplink Range (MHz)	Downlink Range (MHz)	Duplex Mode	Main Region(s)
B1	n1	1920–1980	2110–2170	FDD	Europe, Asia
	n2	1850–1910	1930–1990	FDD	Americas (Asia)
B3	n3	1710–1785	1805–1880	FDD	Europe, Asia (Americas)
B5	n5	824–849	869–894	FDD	Americas, Asia
B7	n7	2500–2570	2620–2690	FDD	Europe, Asia
	n8	880–915	925–960	FDD	Europe, Asia
	n20	832–862	791–821	FDD	Europe
	n28	703–748	758–803	FDD	Asia/Pacific
	n38	2570–2620	2570–2620	TDD	Europe
	n41	2496–2690	2496–2690	TDD	US, China
	n50	1432–1517	1432–1517	TDD	
	n51	1427–1432	1427–1432	TDD	
	n66	1710–1780	2110–2200	FDD	Americas
	n70	1695–1710	1995–2020	FDD	
	n71	663–698	617–652	FDD	Americas
	n74	1427–1470	1475–1518	FDD	Japan
	n75	N/A	1432–1517	SDL	Europe
	n76	N/A	1427–1432	SDL	Europe
	n77	3300–4200	3300–4200	TDD	Europe, Asia
	n78	3300–3800	3300–3800	TDD	Europe, Asia
	n79	4400–5000	4400–5000	TDD	Asia
	n80	1710–1785	N/A	SUL	
	n81	880–915	N/A	SUL	
	n82	832–862	N/A	SUL	
	n83	703–748	N/A	SUL	
	n84	1920–1980	N/A	SUL	

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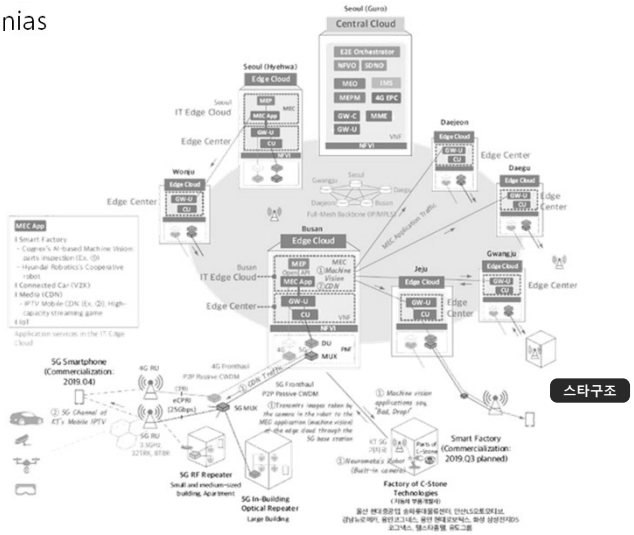
❖ **현재 통신사업자의 망 구성 (KT)** – by Netmanias

kt 5G vs SKT 5GX



Source: https://www.netmanias.com/ko/?m=view&id=oneshot&no=14450

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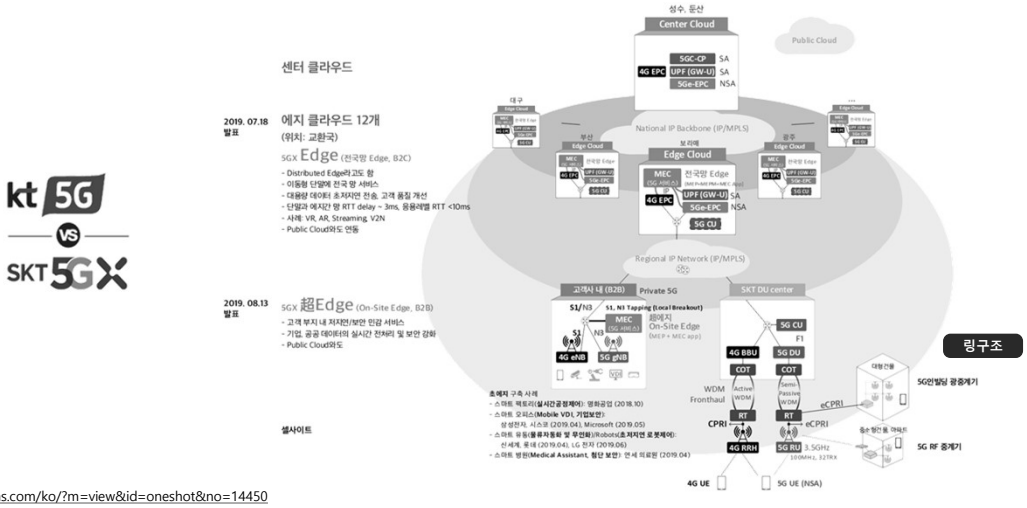
❖ **현재 통신사업자의 망 구성 (SKT)** – by Netmanias



Source: https://www.netmanias.com/ko/?m=view&id=oneshot&no=14450

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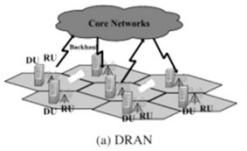
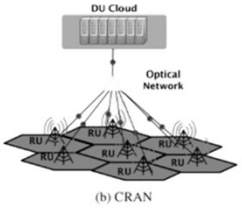
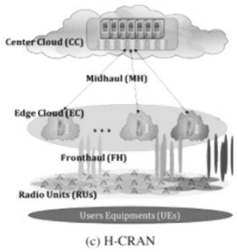
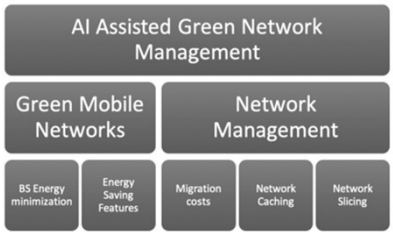
❖ **Data Driven AI Assisted Green Network Design and Management**

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









Source: http://kth.diva-portal.org/smash/get/diva2:1626735/FULLTEXT01.pdf?fbclid=IwAR1F1GlV3bU_YONZzxElLtb4kp_Y7t70VczSb_0ablVqJZxt2ErbJ60UuAg

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❖ 5G NR 기술

- OFDM (Orthogonal frequency-division multiplexing)
- Self-contained slot based framework
- Channel Coding
- MU-MIMO
- mmWave

Source: https://m.post.naver.com/viewer/postView.nhn?volumeNo=11764280&memberNo=20717909

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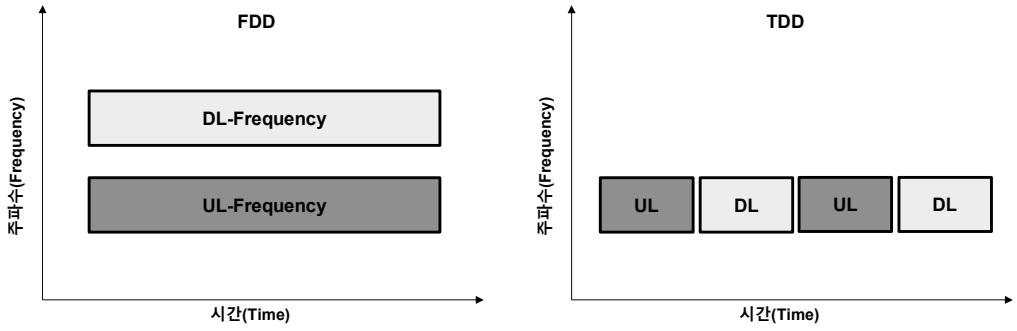
❖ FDD vs. TDD

- Frequency Division Duplex (FDD)
- Time Division Duplex (TDD)



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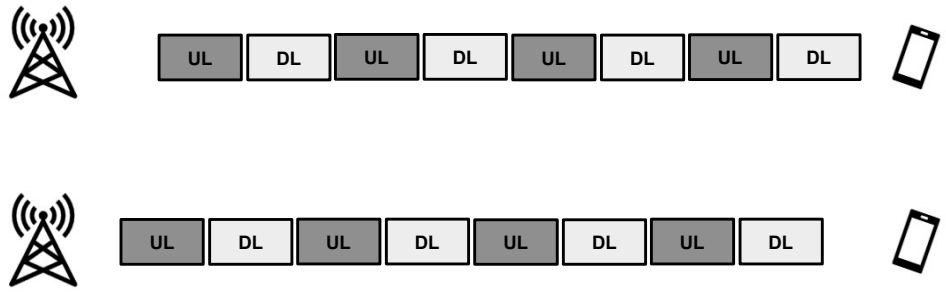
❖ TDD를 위한 동기화 고려



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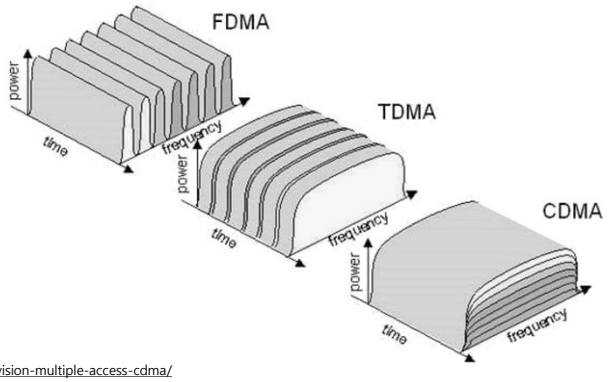
❖ 무선(Radio): 스펙트럼의 물리적 가용성을 향상시키는 방법으로 발전

- 주파수 분할: Frequency Division Multiple Access (FDMA)
- 시간 분할: Time Division Multiple Access (TDMA)
- 코드 분할: Code Division Multiple Access (CDMA)



Source: https://networkencyclopedia.com/code-division-multiple-access-cdma/

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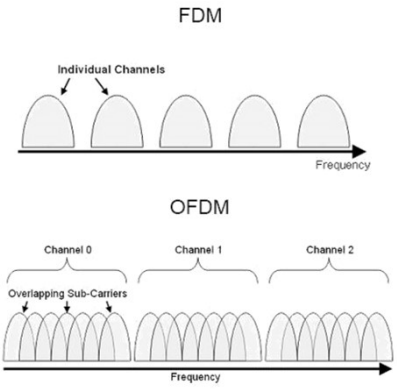
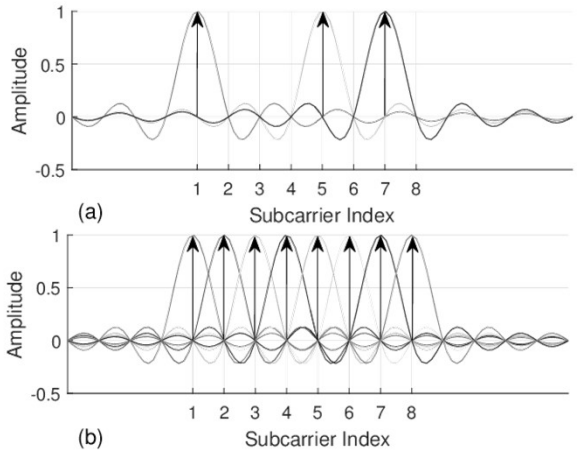
- ❖ **Waveforms and Mixed-Numerology**
- ❖ **Spectrum of OFDM signals with , depicted by the dashed line.**





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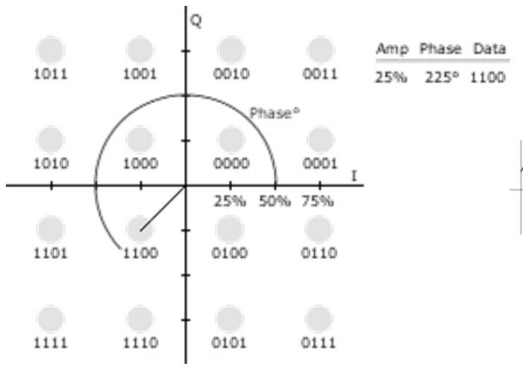
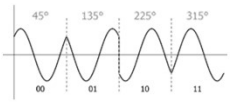
- ❖ **OFDM: Orthogonal Frequency Division Multiplexing**
- ❖ **QAM은 signal space(신호 공간) 개념과 복소평면을 사용 constellation 표현**

16-QAM의 constellation (예)



Amp	Phase	Data
25%	225°	1100



64-QAM의 constellation (예)

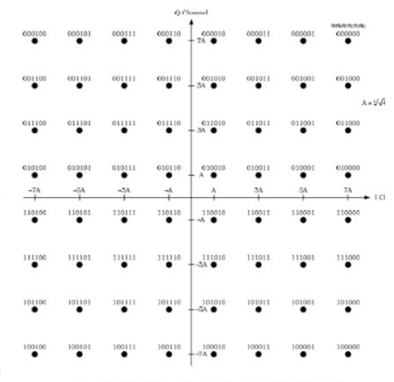


Figure 2.6.7.4-1. Signal Constellation for 64-QAM Modulation

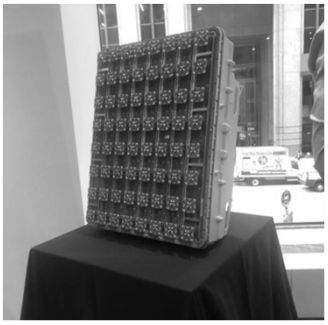
Source: https://namu.wiki/w/%EB%B3%80%EC%A1%B0(%ED%86%B5%EC%8B%A0)

DAY 2: ENHANCED MOBILE BROADBAND

❖ Massive MIMO (예)

64 TX + 64 RX 5G MU-MIMO antenna suitable for Massive MIMO, (Credit: Ericsson)

Aurora CMM.100.A 5-6GHz C-Band Massive MIMO Phased Array



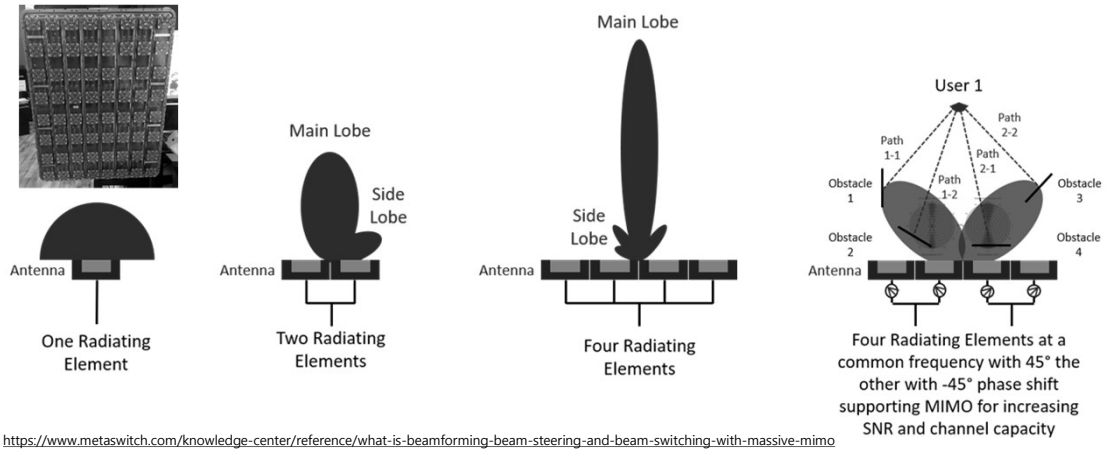
Massive MIMO has traditionally been used in TDD bands. (Bevin Fletcher/FierceWireless)

Source: https://medium.com/5g-nr/massive-mimo-75f775ead2e9
Source: https://www.fiercewireless.com/tech/t-mobile-exec-says-massive-mimo-can-be-used-tdd-and-fdd-bands

DAY 2: ENHANCED MOBILE BROADBAND

❖ 빔포밍 (What is 5G beamforming?)

• 무선의 위상제어(Beam steering): 위상변화를 수신자 목표로 지향성 무선 신호를 송신

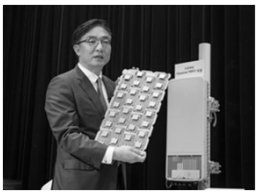


Source: https://www.metaswitch.com/knowledge-center/reference/what-is-beamforming-beam-steering-and-beam-switching-with-massive-mimo

DAY 2: ENHANCED MOBILE BROADBAND

❖ 5G RAN 기기

- RRH(Remote Radio Head): RU를 외장형으로 구성
- 통신부품
  - RF 필터
  - 안테나
  - 광트랜스퍼
  - RRH 케이스
- MUX: 프론트홀(RU-DU) 연결
- 중계기
  - 광중계기 (DAS: Distributed Antenna System)
  - RF 중계기 (ICS: Interference Cancellation System)
- DU (Distributed Unit)
- CU (Centralized Unit)



Kim Young-ki, head of Samsung Electronics' network business division, shows the firm's 5G network gear in a press conference at the tech firm's headquarters in Suwon, Gyeonggi Province, July 13. / Courtesy of Samsung Electronics

- 중계기 기업 (기타)
  - 에프알텍
  - CS
  - 기산텔레콤 등

5G 주요 업체 List

	주요 제품 및 사업	주요 기업
무선통신장비	안테나, RRH, RF부품	케이엠더블유, 에이스테크
	광트랜시버	오이솔루션
	프론트홀 장비	에치에프알, 쏠리드
	중계기	에치에프알, 쏠리드
	기지국 장비 케이스	서진시스템
	GaN트랜지스터	RFHIC
유선네트워크장비	FTTX, 스위치 장비	유비쿼스, 다산네트웍스, 에치에프알, 머큐리
	광트랜시버	오이솔루션
시험인증	인증	에이치시티

자료: 신한금융투자

Source: https://m.blog.naver.com/PostView.naver?isHttpsRedirect=true&blogId=atlasstock&logNo=221559939410

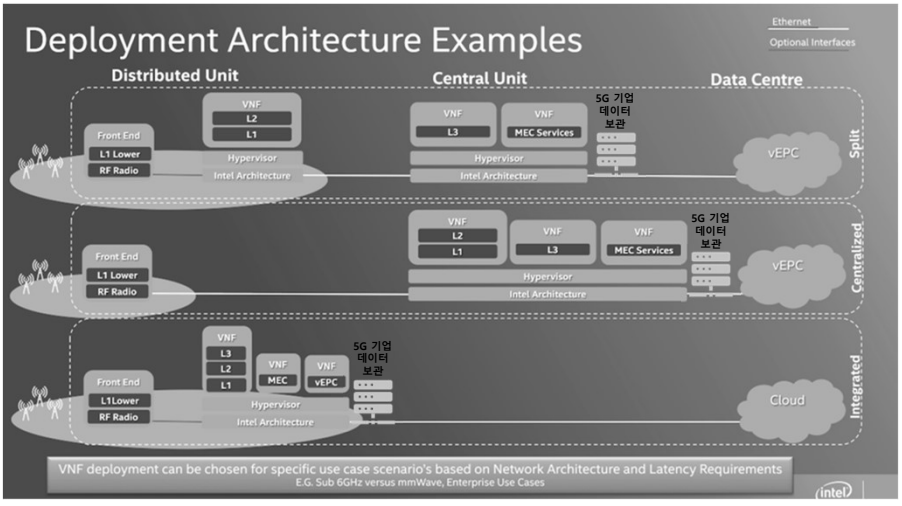
DAY 2: ENHANCED MOBILE BROADBAND

❖ 5G RAN 구성 (예): 인텔의 FlexRAN

분할(Split)

중앙집중(Centralized)

통합(Integrated)



DAY 2: ENHANCED MOBILE BROADBAND

❖ **V2X Standards (L1 & L2)**

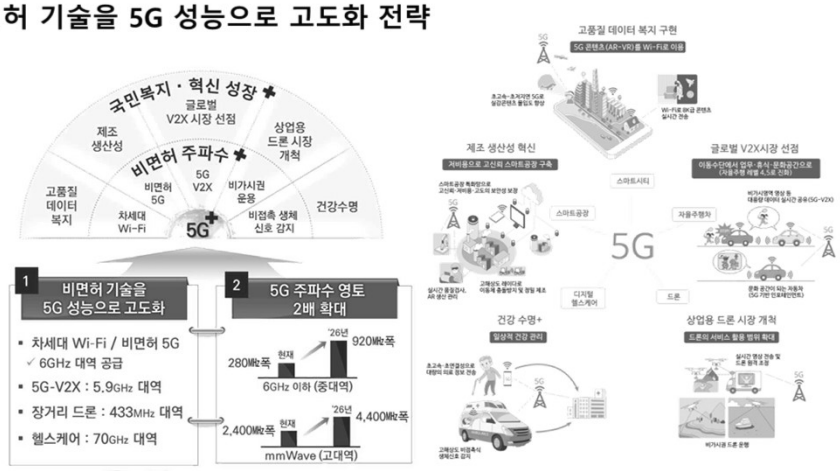
	5G NR V2X (sidelink)	LTE V2X (sidelink)	802.11p
Max. Bandwidth @ sub 6GHz	40 MHz (Flexible) (>150Mbps)	20 MHz (~ 70 Mbps)	20 MHz (54 Mbps)
ITS channel (Korea)	-	-	Multichannel 10 MHz
ITS channel (US*)	-	20 MHz	10 MHz
Comm. Type	Broadcast, Groupcast, Unicast	Broadcast	Broadcast
Retransmission	HARQ	HARQ (blind)	-
Resource Selection	Mode 1 (gNB centralized) Mode 2 (UE sensing based)	Mode 3 (eNB centralized) Mode 4 (UE sensing based)	*CSMA-CA*
Modulation	QPSK, 16QAM, 64QAM, 256QAM	QPSK, 16QAM, 64QAM	BPSK, QPSK, 16QAM, 64QAM
Channel Coding	LDPC / Polar	Turbo	Convolutional
Waveform	OFDM	SC-FDM	OFDM

Source: US FCC Nov. 2019. US FCC FNPRM Oct. 28 2020 will be explained later session

DAY 2: ENHANCED MOBILE BROADBAND

❖ **비면허 주파수 기술과 서비스**

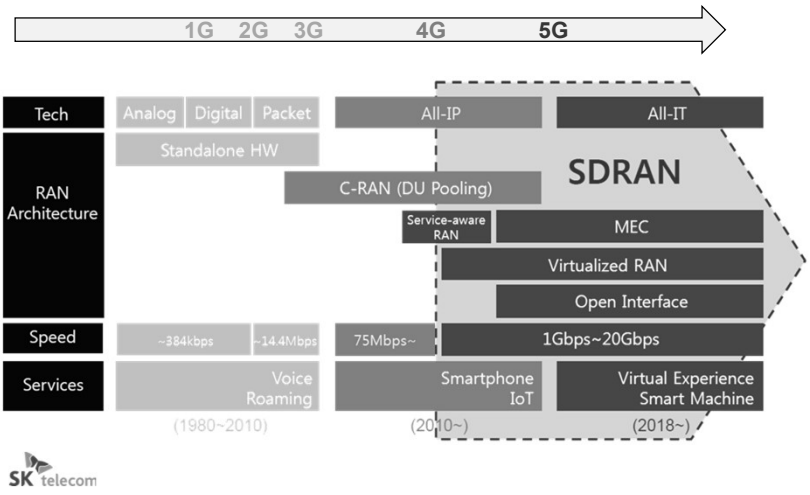
❖ **5G와 결합·보조하는 비면허 기술을 5G 성능으로 고도화 전략**



Source: 5G+ 스펙트럼 플랜, 과학기술정보통신부

DAY 2: ENHANCED MOBILE BROADBAND

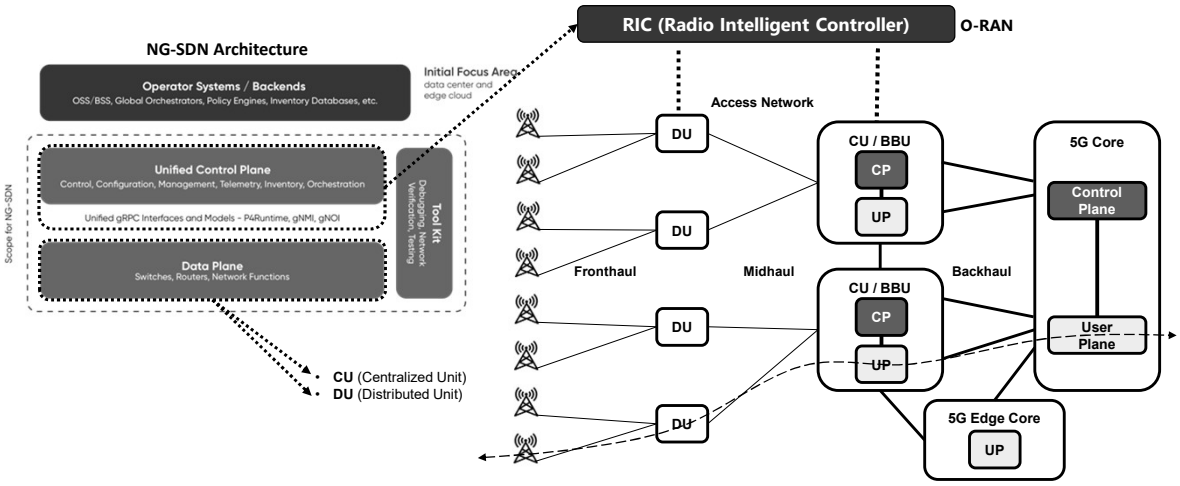
❖ 5G의 소프트웨어 정의 무선 (SDRAN) 환경



JS Lab

DAY 2: ENHANCED MOBILE BROADBAND

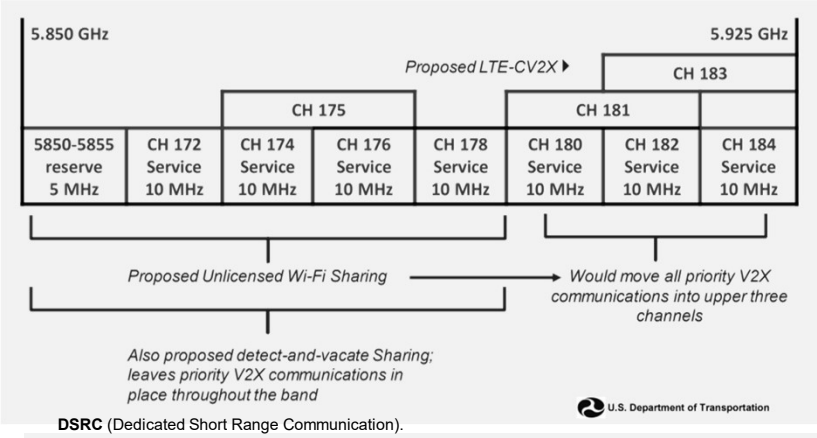
❖ O-RAN과 '프론트홀/미드홀/백홀'



JS Lab

DAY 2: ENHANCED MOBILE BROADBAND

❖ US 5G NR V2X case



DSRC (Dedicated Short Range Communication).

V2X용으로 할당되었던 5.9GHz 대역 7개 채널 중 하위 4개 채널을 WiFi에 할당하고 상위 3개 채널을 C-V2X에 할당

DAY 2: ENHANCED MOBILE BROADBAND

❖ Sidelink communications for V2X

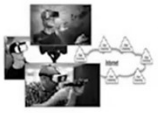
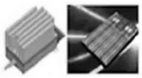
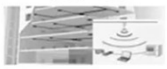
- V2V
- V2I

Source: https://eu.mouser.com/blog/eit-5g-2021-6-key-aspects-3gpp-5-release-16

DAY 2: ENHANCED MOBILE BROADBAND

❖ **IITP 2025 RnD 추진**

• **IITP R&D 핵심 이슈:** 동작 주파수 고대역화, 융합 서비스 보편화, 소프트웨어 중심 설계화

구분		2020	2021	2022	2023	2024	2025
네트워크	서비스		실감형 에지 응용서비스 	5G 버티컬 산업망 서비스 		네트워크 자동화 서비스 	분산 AI서비스 
	제품	5G 실내 분산 안테나 시스템 	400G 광송수신 모듈 	16T급 POTN 	5G+ 코어 및 TSN 스위치 	800G 광송수신 모듈 	광기반 Sub-THz 부품/모듈 

Source: IITP 정보통신 평가 기획원

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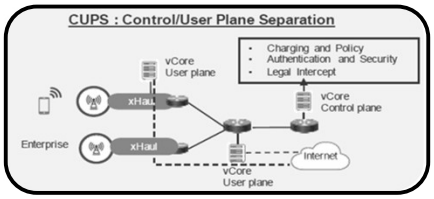
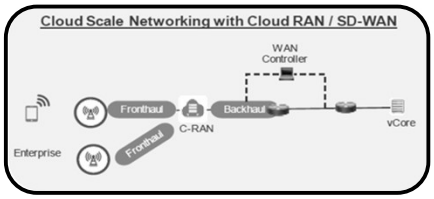
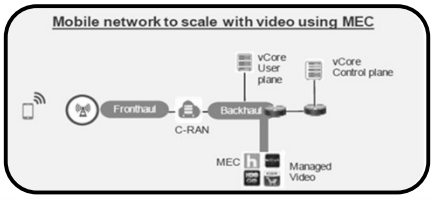
DAY 2: ENHANCED MOBILE BROADBAND

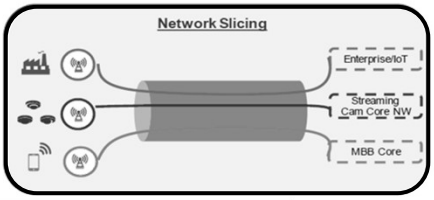
❖ **5G Enabling Technologies:**

- **CUPS** (제어/사용자 플레인 분리)
- **Cloud Scale** (클라우드 스케일)
- **MEC** (모바일 에지 컴퓨팅)
- **Network Slicing**









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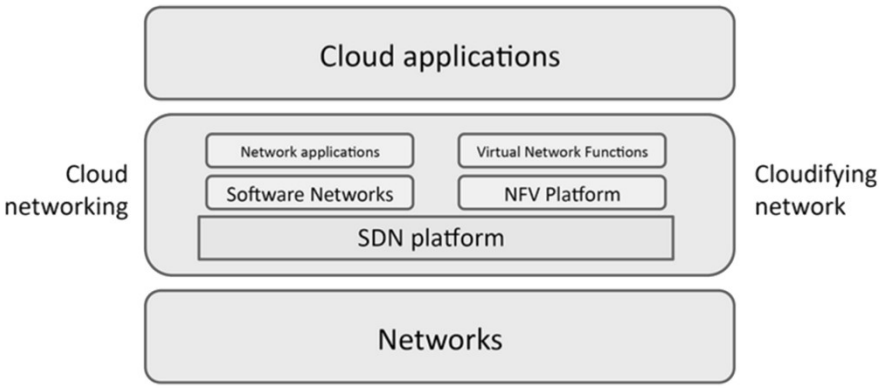
DAY 2: ENHANCED MOBILE BROADBAND

❖ SDN

• The overall architecture of SDN solutions

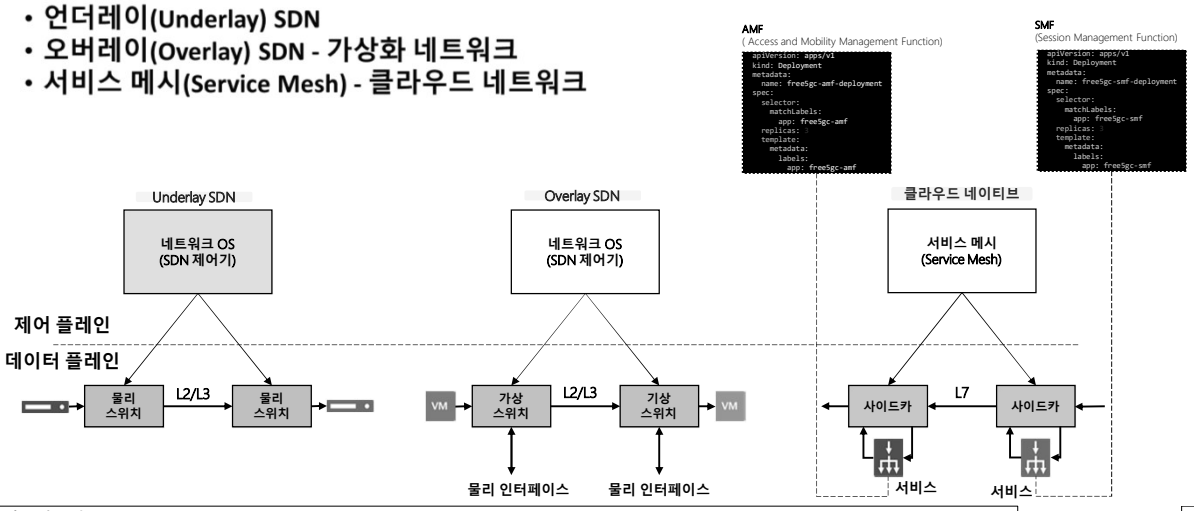


Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

DAY 2: ENHANCED MOBILE BROADBAND

❖ 자동화를 위한 소프트웨어 정의 네트워크(SDN) 기술 확장

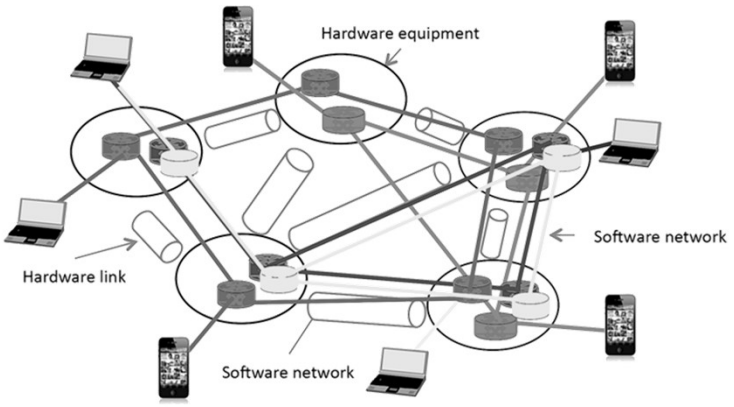
• 언더레이(Underlay) SDN
• 오버레이(Overlay) SDN - 가상화 네트워크
• 서비스 메시(Service Mesh) - 클라우드 네트워크



DAY 2: ENHANCED MOBILE BROADBAND

❖ Virtualization

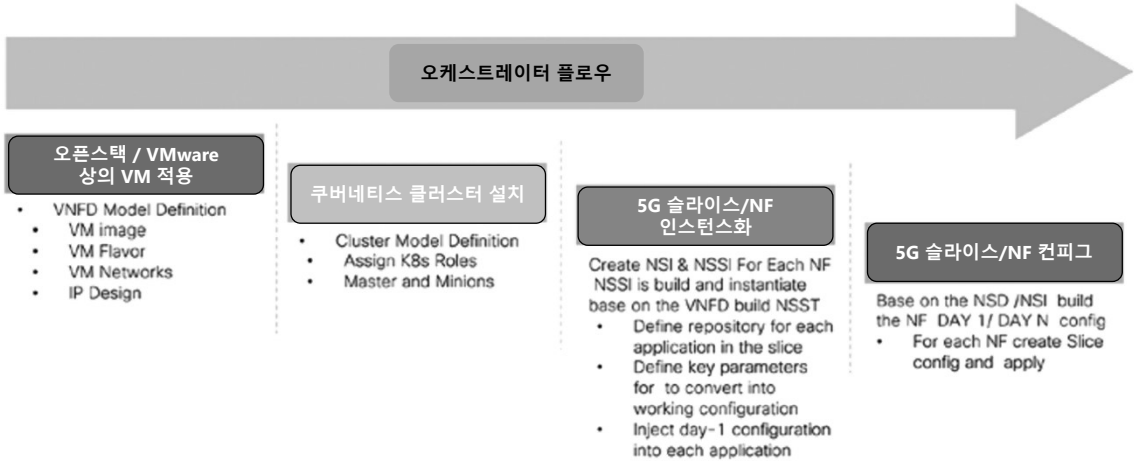
- A set of software networks.
- 네트워크 슬라이싱



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

DAY 2: ENHANCED MOBILE BROADBAND

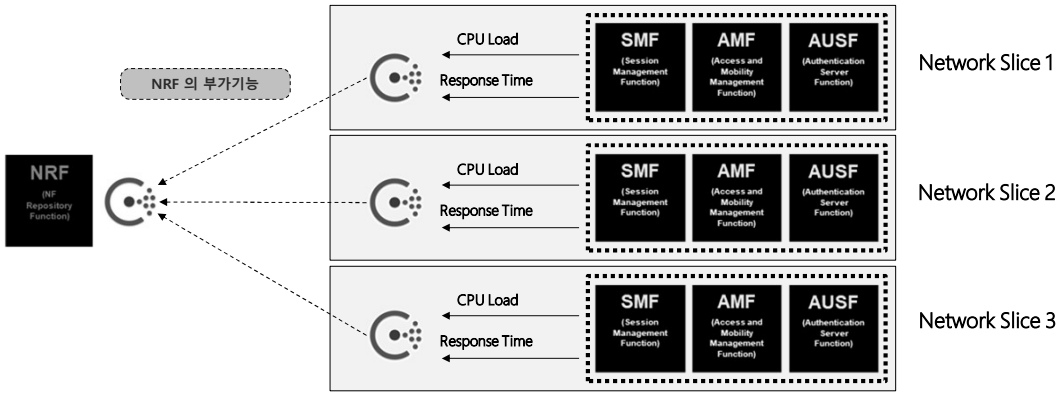
❖ 5G core NF and slice creation



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

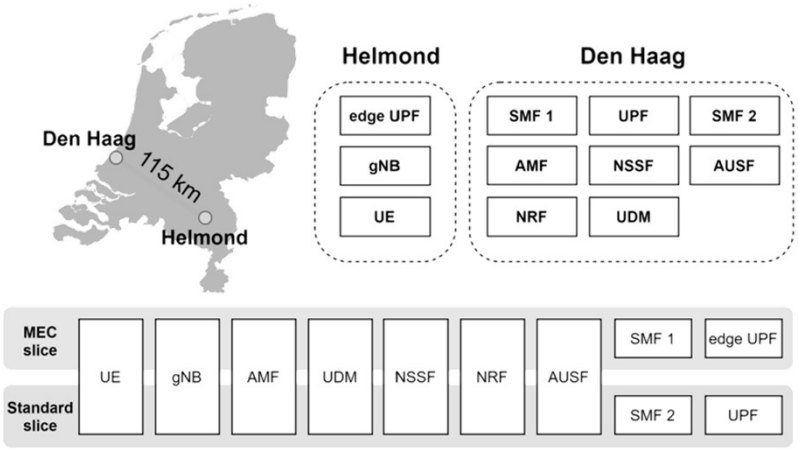
DAY 2: ENHANCED MOBILE BROADBAND

- ❖ Management 부가 기능: Consul Cluster (HashiCorp)
- ❖ Management Trend 고려: Service Mesh (Istio)



DAY 2: ENHANCED MOBILE BROADBAND

- ❖ Configurations of multi-slice UE in 5G SA with MEC

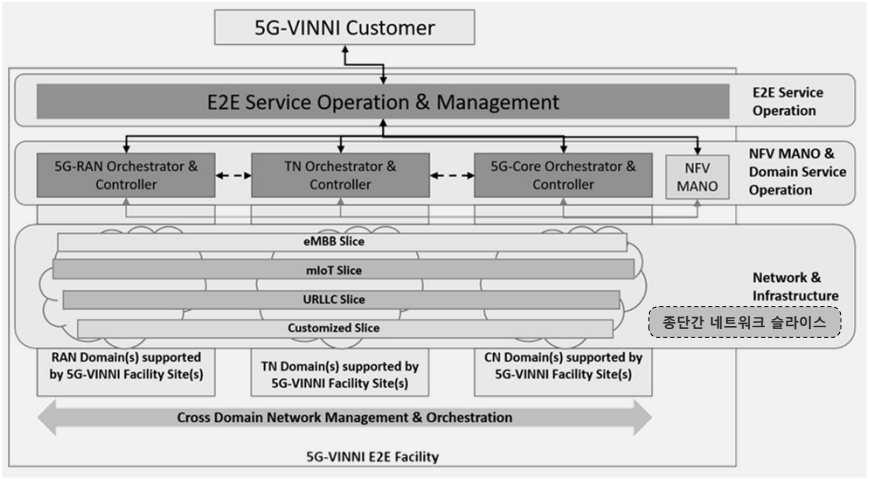


Source: 5GPPP Architecture Working Group, 5G Architecture White Paper

DAY 2: ENHANCED MOBILE BROADBAND

❖ **E2E Network Slicing Architecture**

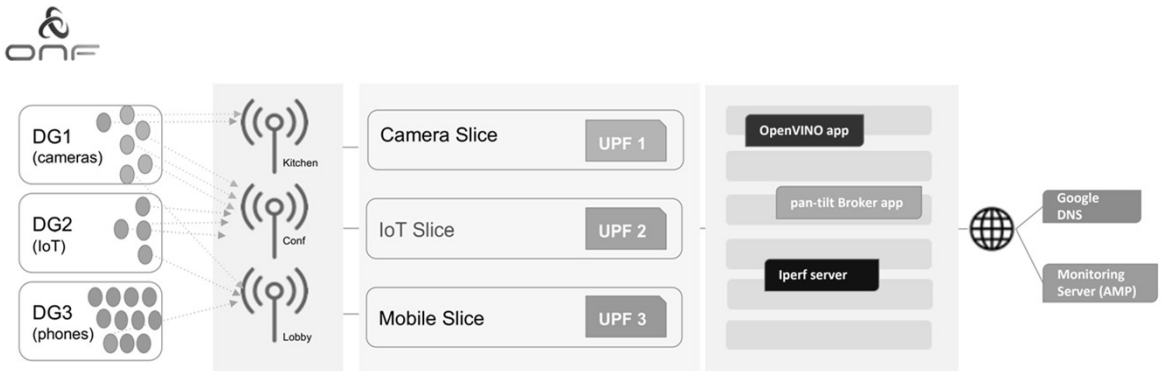
Architectural solution	5G PPP Project
Slice ordering architecture and lifecycle management	5G VINNI
Slice Manager	5GENESIS
Composition and sharing of end-to-end network slices for vertical service arbitration	5Growth



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

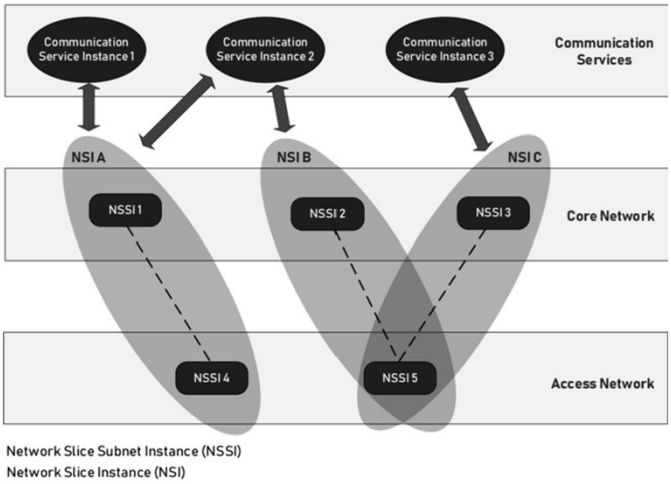
DAY 2: ENHANCED MOBILE BROADBAND

❖ **Sample Enterprise Network**



DAY 2: ENHANCED MOBILE BROADBAND

❖ 3GPP Slicing model

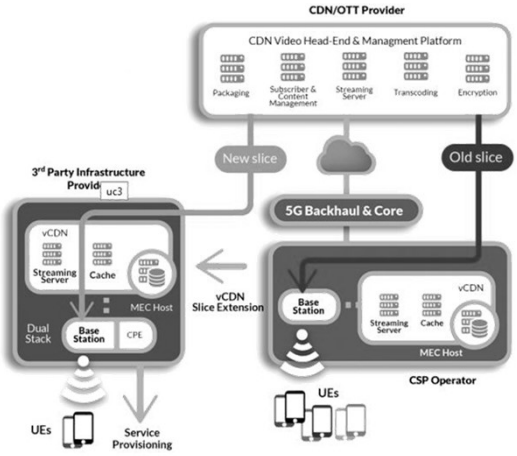


Source: Report on infrastructure-level enablers for 5G!Drones, European Union's Horizon 2020 research and innovation programme under grant agreement No 857031.

DAY 2: ENHANCED MOBILE BROADBAND

❖ vCDN use-case with elastic MEC-enabled slices

vCDN의 스케일아웃 확장

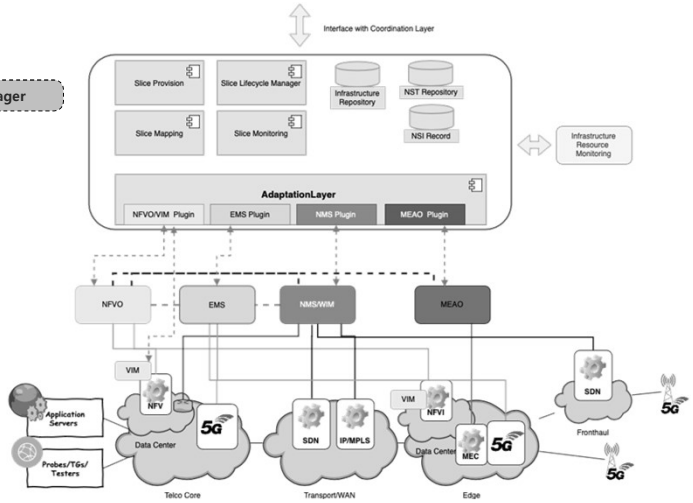


Source: 5GPPP Architecture Working Group, 5G Architecture White Paper

DAY 2: ENHANCED MOBILE BROADBAND

❖ **Slice Manager Architecture**

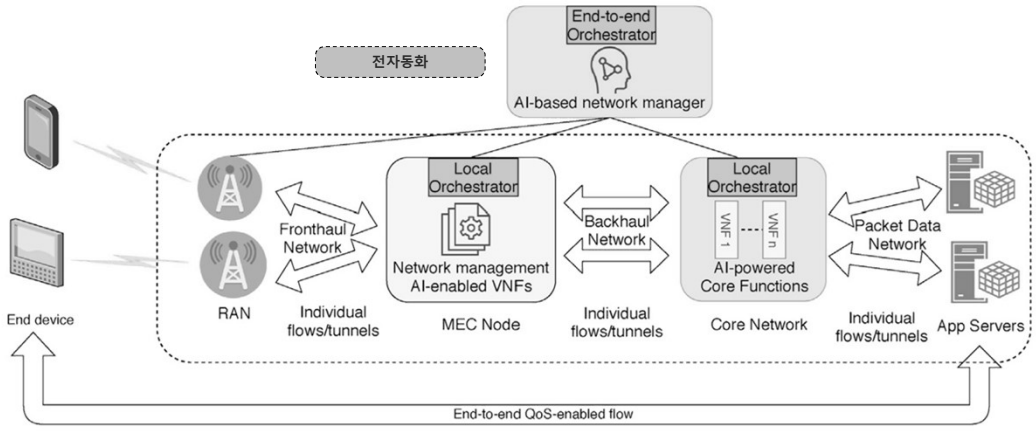
Architectural solution	5G PPP Project
Slice ordering architecture and lifecycle management	5G VINNI
Slice Manager	5GENESIS
Composition and sharing of end-to-end network slices for vertical service arbitration	5Growth



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

DAY 2: ENHANCED MOBILE BROADBAND

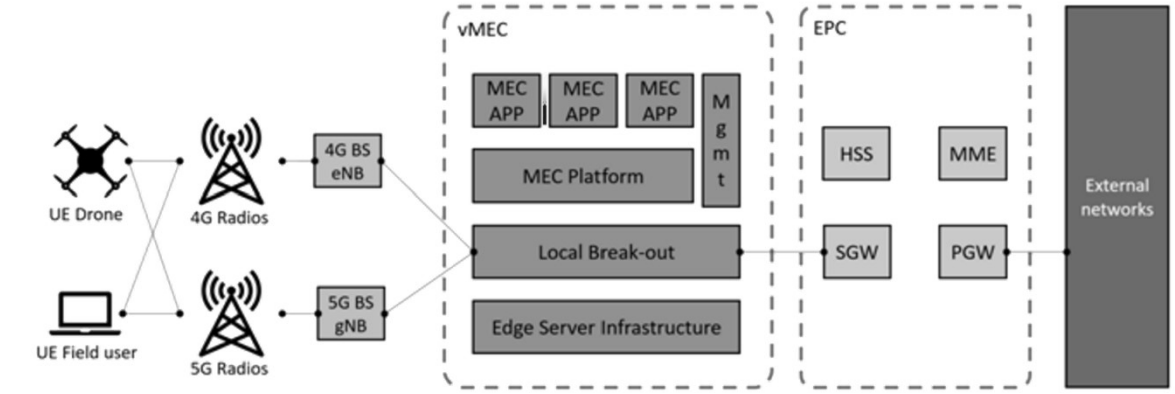
❖ **Overall Zero-touch Network and Service Management (ZSM) vision.**



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

DAY 2: ENHANCED MOBILE BROADBAND

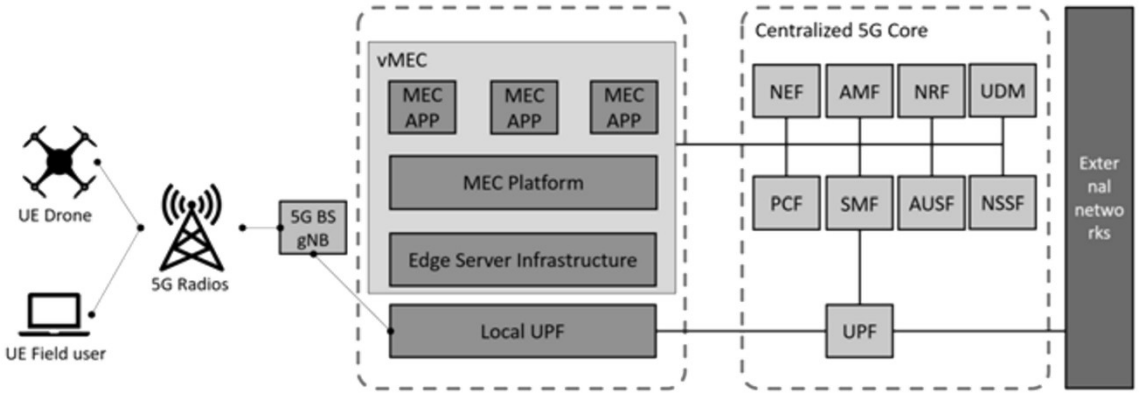
❖ 5GTN MEC deployment in NSA mode



Source: Report on infrastructure-level enablers for 5G!Drones, European Union's Horizon 2020 research and innovation programme under grant agreement No 857031.

DAY 2: ENHANCED MOBILE BROADBAND

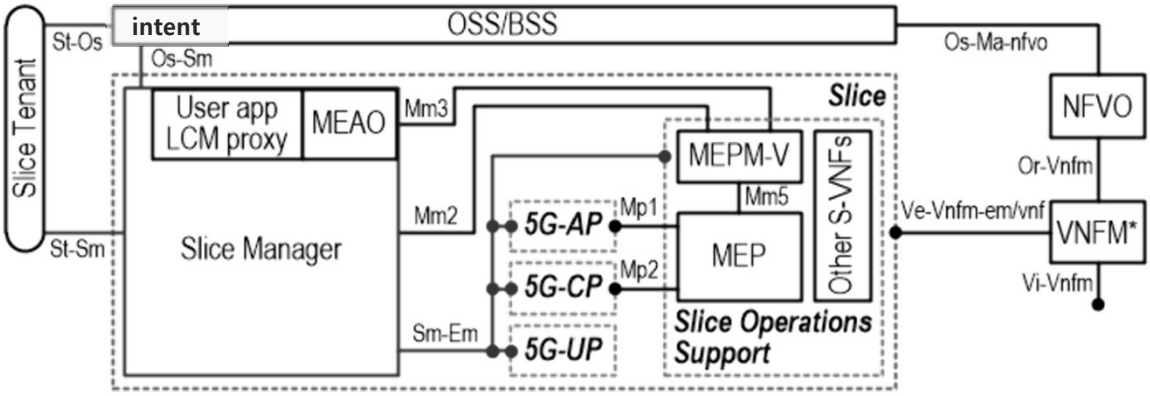
❖ 5GTN MEC deployment in SA mode



Source: Report on infrastructure-level enablers for 5G!Drones, European Union's Horizon 2020 research and innovation programme under grant agreement No 857031.

DAY 2: ENHANCED MOBILE BROADBAND

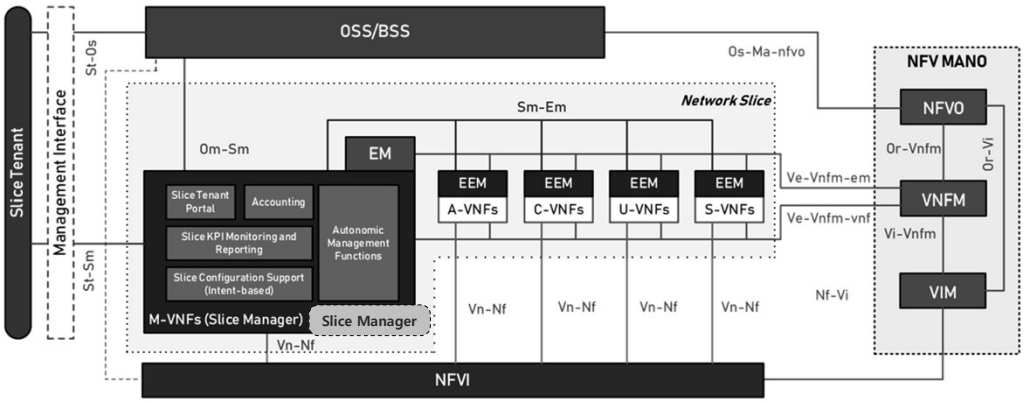
❖ **MEC-enabled intent-based management architecture**



Source: Report on infrastructure-level enablers for 5G!Drones, European Union's Horizon 2020 research and innovation programme under grant agreement No 857031.

DAY 2: ENHANCED MOBILE BROADBAND

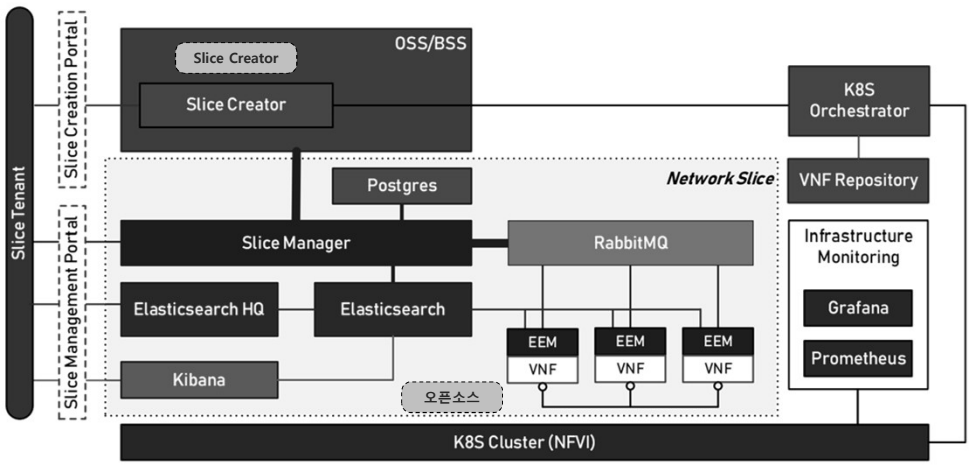
❖ **Intent-based management framework with the internal structure of network slices – ETSI NFV MANO extensions (slice management plane shown in navy blue)**



Source: Report on infrastructure-level enablers for 5G!Drones, European Union's Horizon 2020 research and innovation programme under grant agreement No 857031.

DAY 2: ENHANCED MOBILE BROADBAND

❖ Exemplary implementation of ISM utilizing K8s as the VNF orchestrator

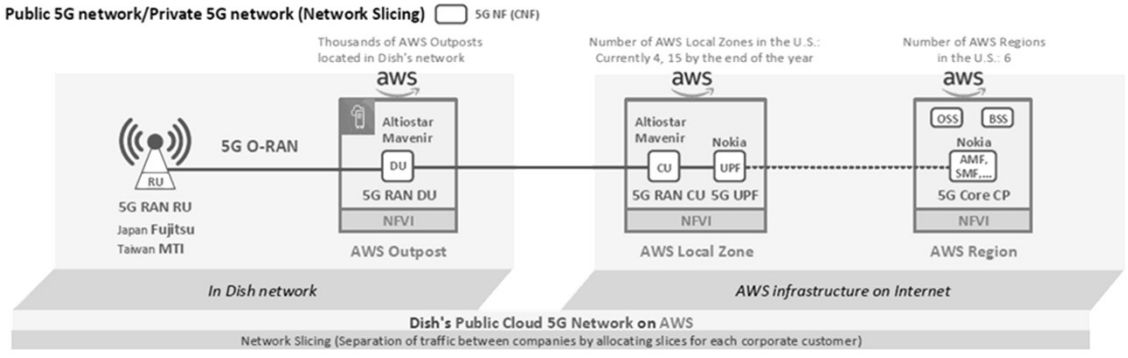


Source: Report on infrastructure-level enablers for 5G!Drones, European Union's Horizon 2020 research and innovation programme under grant agreement No 857031.

DAY 2: ENHANCED MOBILE BROADBAND

❖ 네트워크 슬라이싱

• Public 5G 네트워크 / Private 5G 네트워크

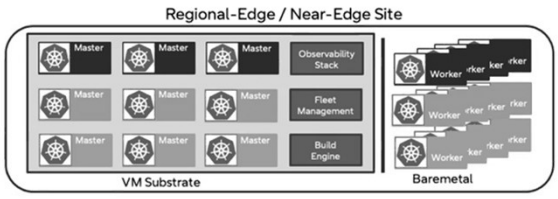


Source: Netmanias

DAY 2: ENHANCED MOBILE BROADBAND

❖ Edge Pattern for Infra

- Multi-Cluster
- Standalone

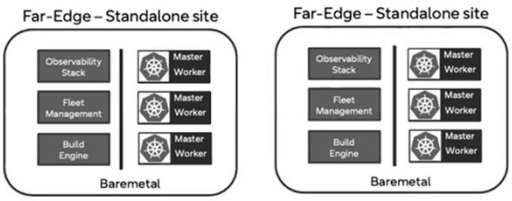


1. High Security Multi-Cluster

- Regional or Near-edge site supporting multiple racks of compute
- Multi-cluster, for different function types e.g. RAN 'vs' AR/VR Cache
- VMs provide security and efficiency for hosting K8s-masters and supporting functions, in a multi-cluster environment

2. Standalone

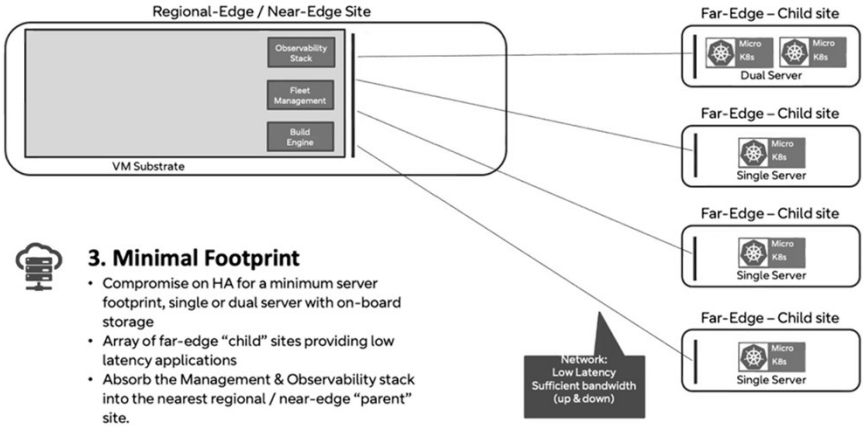
- Low Compute e.g. Single Racks, with local or software-defined storage
- Lower Latency / High Performance Edge
- Standalone, dedicated applications, with HA and supporting mgmt. functions e.g. Private Network Edge



DAY 2: ENHANCED MOBILE BROADBAND

❖ Edge Pattern for Infra

- Minimal Footprint

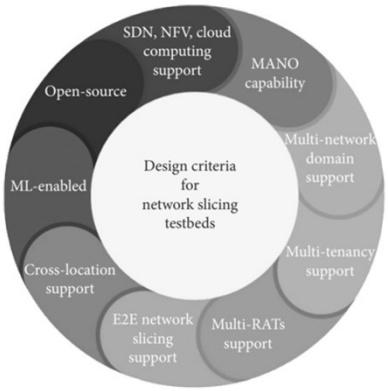


3. Minimal Footprint

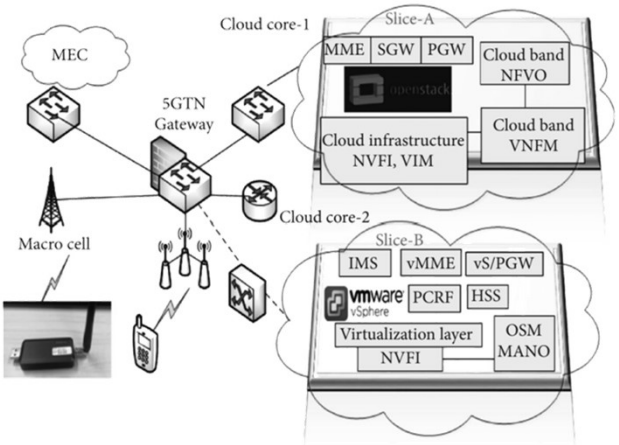
- Compromise on HA for a minimum server footprint, single or dual server with on-board storage
- Array of far-edge "child" sites providing low latency applications
- Absorb the Management & Observability stack into the nearest regional / near-edge "parent" site.

DAY 2: ENHANCED MOBILE BROADBAND

❖ 5GTN testbed architecture (OpenStack / VMware)



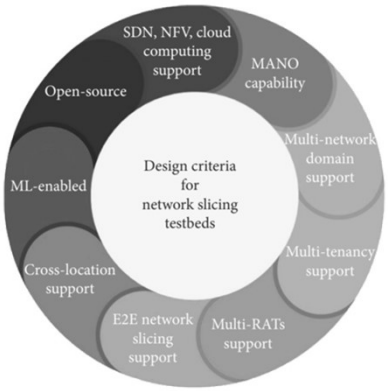
Design criteria for network slicing testbeds.



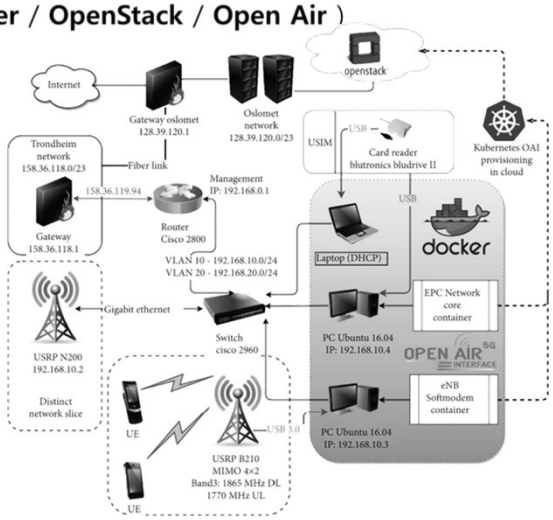
Source: Wireless Communications and Mobile Computing, Volume 2021, Article ID 6655216, 26 pages, https://doi.org/10.1155/2021/6655216

DAY 2: ENHANCED MOBILE BROADBAND

❖ 5G for IoT testbed architecture (K8s / Docker / OpenStack / Open Air)



Design criteria for network slicing testbeds.



Source: Wireless Communications and Mobile Computing, Volume 2021, Article ID 6655216, 26 pages, https://doi.org/10.1155/2021/6655216

DAY 2: ENHANCED MOBILE BROADBAND

❖ Comparison of small-scale testbeds for network slicing in 5G,

- denotes supported feature
- denotes unsupported feature

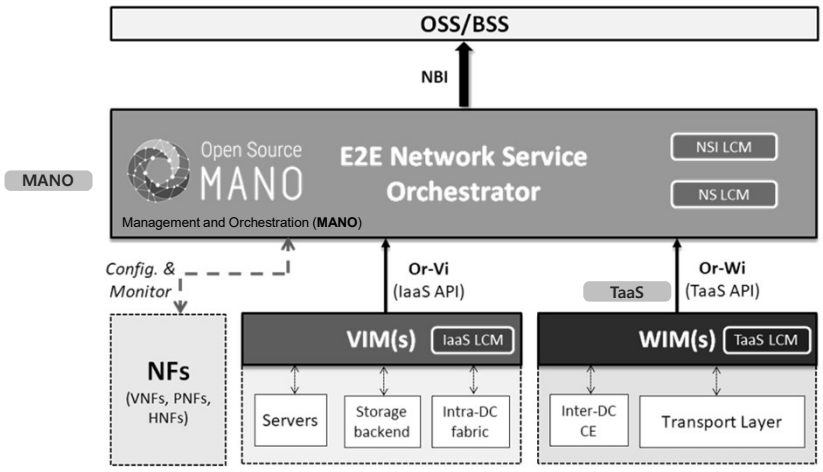
Testbed	SDN	NFV	Cloud comp.	Multi-domain	Multi-tenancy	MANO	Multi-RATs	E2E slicing	Cross-location	ML-enabled	Open-source	MANO type
1. 5G4IoT [38, 39]	✓	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗
2. 5GTN [40]	✓	✓	✓	✓	✗	✓	✓	✗	✗	✗	✓ (https://5gtn.fi/)	OSM, CloudBand
3. SEMIoTICS [41]	✓	✓	✓	✓	✓	✓	✗	✓	✗	✗	✓ (https://www.semiotics-project.eu/)	OpenStack tacker
4. Mosaic5G [43]	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓ (http://mosaic5g.io/)	JOX
5. Orion [45, 46]	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✗	OSM and a customized orchestrator
6. 5G Testbed for NS [47]	✗	✓	✓	✓	✗	✗	✗	✓	✗	✗	✓ (https://github.com/ashxz47)	✗
7. POSENS [48, 49]	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓ (https://github.com/wnlUc3m)	Customized OSM
8. UPC testbed [50]	✓	✓	✗	✓	✓	✗	✓	✗	✗	✓	✗	✗
9. M-CORD based testbed [52, 53]	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓ (https://nick133371 github.io/)	XOS
10. NS for 5G IoT and eMBB [55]	✓	✓	✓	✓	✓	✗	✓	✗	✗	✗	✗	✗
11. Transformable resources slicing testbed [56]	✓	✓	✓	✗(E2E slice traverses over RAN, TN and CN.)	✓	✓	✗	✗	✗	✗	✗	VLSP, Kubernetes, and OpenStack
12. DSAF [58]	✗	✓	✓	✗	✗	✓	✗	✗	✗	✗	✗	Customized python-based orchestrator
13. SliceNet [59]	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	OSM, OpenBaton
14. IqInf testbed [60]	✓	✓	✗	✓	✗	✗	✓	✗	✗	✗	✗	✗
15. Slice-aware SA testbed [61]	✓	✓	✗	✗	✗	✓	✗	✗	✗	✗	✗	Service assurance integrated with MANO
16. Simula [62, 63]	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✓ (https://github.com/simula/5gvinni-oai-ns)	OSM
17. 5GIIK [64, 65]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ (https://bit.ly/3qOqd6)	OSM
18. ONAP based testbed [67]	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	ONAP
19. BlueArch [68]	✓	✓	✓	✓	✗	✓	✗	✗	✗	✗	✗	Open MANO, RIFT.io
20. MEC IoT platform [69, 70]	✓	✓	✓	✓	✗	✓	✓	✗	✗	✗	✗	OSM
21. CAI [71]	✓	✓	✓	✓	✗	✗	✓	✗	✗	✓	✓ (https://bit.ly/3tXEr5X)	✗

ONAP

Source: Wireless Communications and Mobile Computing, Volume 2021, Article ID 6655216, 26 pages, https://doi.org/10.1155/2021/6655216

DAY 2: ENHANCED MOBILE BROADBAND

❖ OSM service platform architecture.

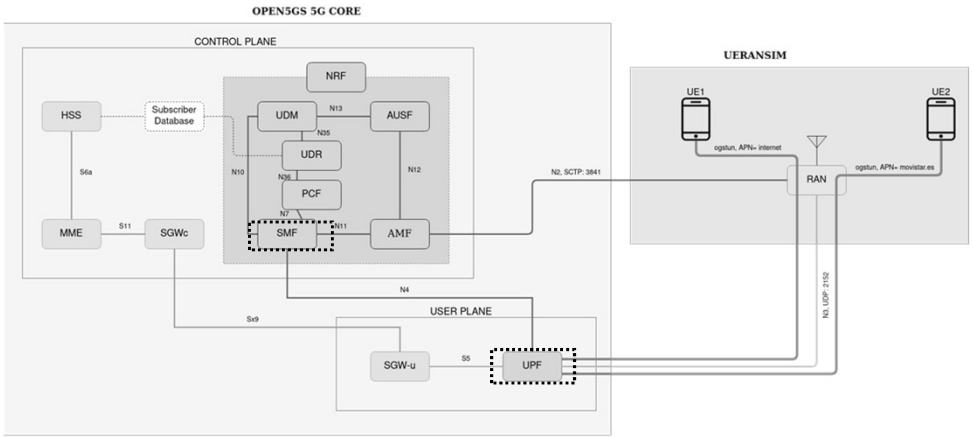


Source: VIRTUALIZED CELLULAR NETWOKS WITH NATIVE CLOUD FUNCTIONS, Iria Míguez González

DAY 2: ENHANCED MOBILE BROADBAND

❖ **Configuration of different AMBR**(Aggregate Maximum Bit Rate) **per slice**

• **Architecture of the Network for the test**

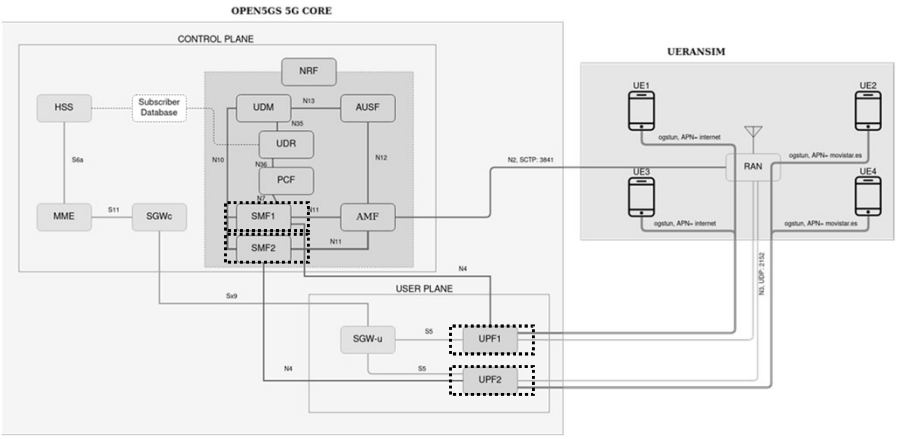


Source: VIRTUALIZED CELLULAR NETWOKS WITH NATIVE CLOUD FUNCTIONS, Iria Míguez González

DAY 2: ENHANCED MOBILE BROADBAND

❖ **Selection of UPF and SMF by slice**

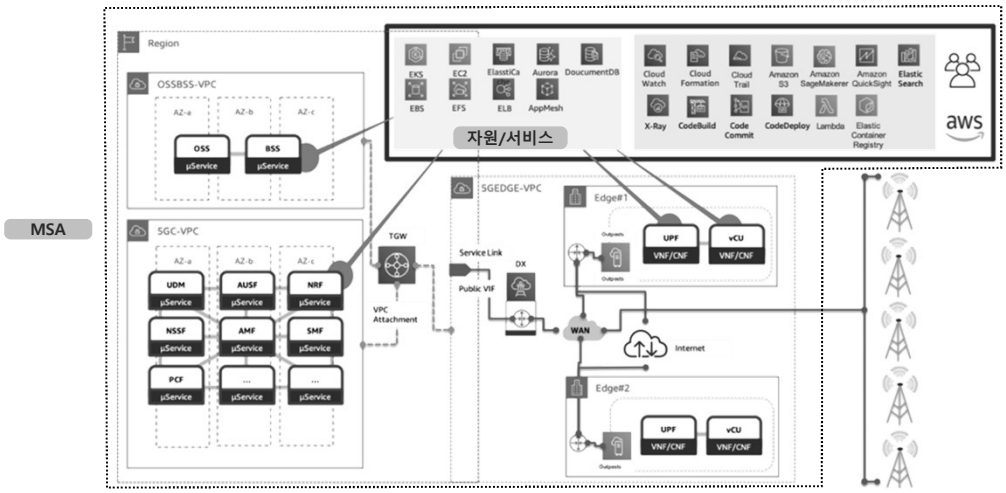
• **iperf Slicing Test Architecture (K8s 시연)**



Source: VIRTUALIZED CELLULAR NETWOKS WITH NATIVE CLOUD FUNCTIONS, Iria Míguez González

DAY 2: ENHANCED MOBILE BROADBAND

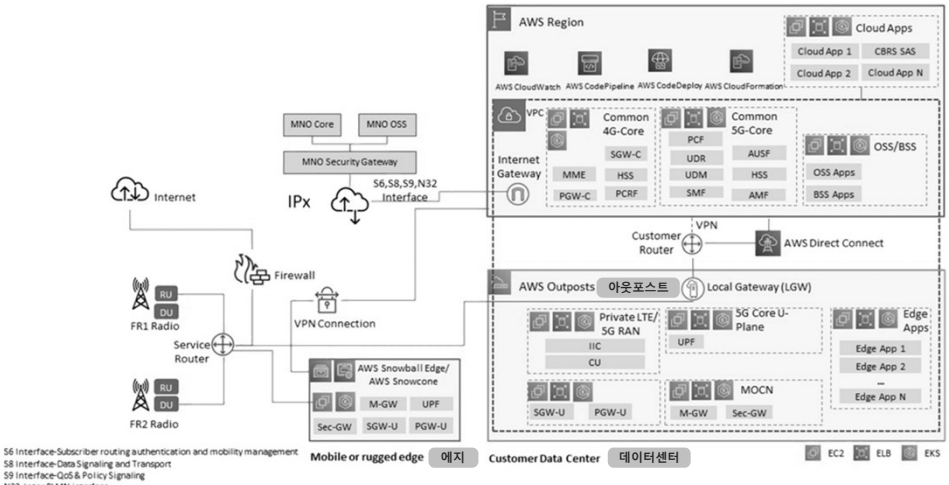
❖ **Reference architecture of 5G network (AWS)**



Source: 5G Network Evolution with AWS, July 2020

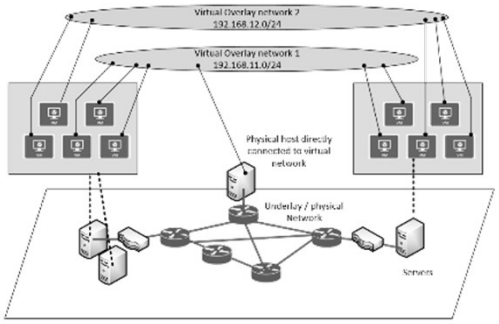
DAY 2: ENHANCED MOBILE BROADBAND

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



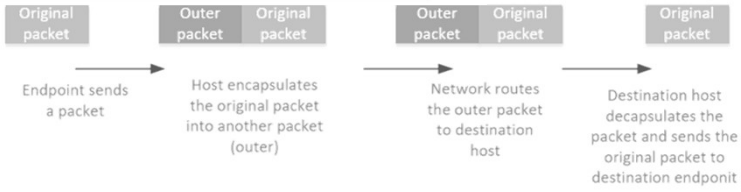
DAY 2: ENHANCED MOBILE BROADBAND

❖ **Packet Transfer Steps in an Overlay Network**



VXLAN **(Virtual Extensible LAN) 사용시 고려**

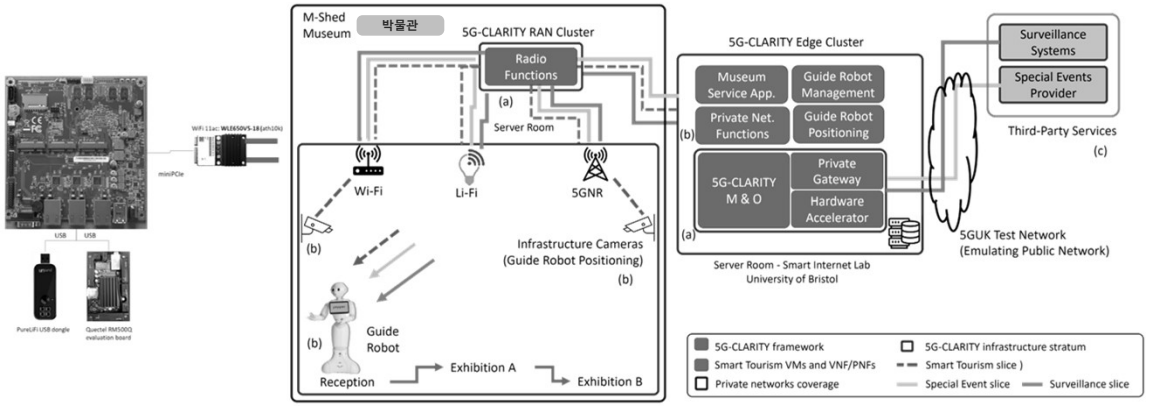
- **Maximum Ethernet Frame Size**
- **Multicast**



DAY 2: ENHANCED MOBILE BROADBAND

❖ **5G-CLARITY proposed architecture**

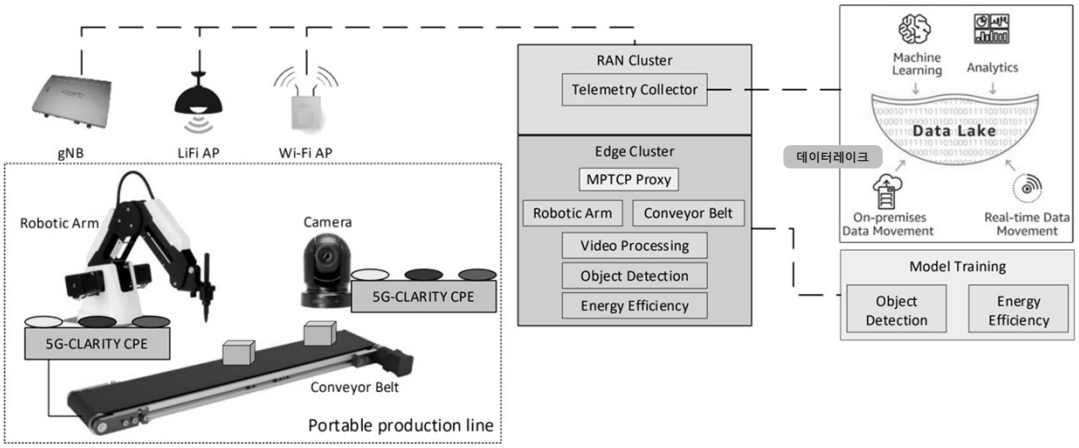
- **UC1 framework, components and service slices overview**
- **5G-CLARITY CPE preliminary design**



Source: 5G-CLARITY [H2020-871428], Mir Ghoraishi(GIGASYS)

DAY 2: ENHANCED MOBILE BROADBAND

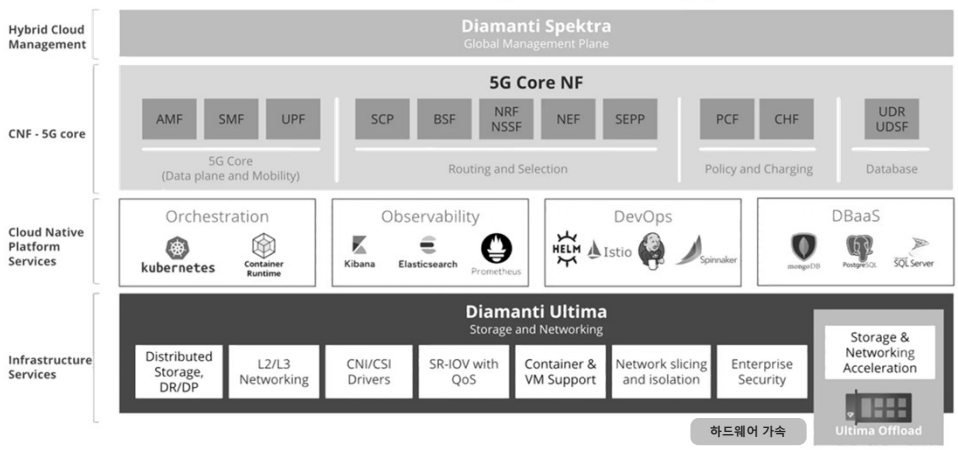
❖ **Production line testbed and its integration to 5G-CLARITY system architecture**



Source: 5G-CLARITY [H2020-871428], Mir Ghoraishi(GIGASYS)

DAY 2: ENHANCED MOBILE BROADBAND

❖ **Full Stack for running 5G core** (예: Diamanti)

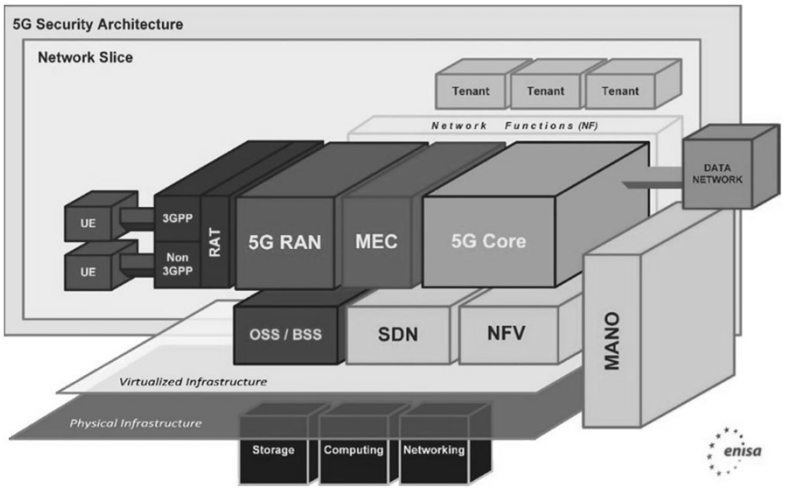


Source: https://diamanti.com/tutorial-5g-core-on-diamanti/

DAY 2: ENHANCED MOBILE BROADBAND

❖ 네트워크 슬라이싱 (예): **ENISA**(European Union Agency for Cybersecurity)

슬라이스별 5G 보안 아키텍처



Source: ENISA 5G Security Architecture

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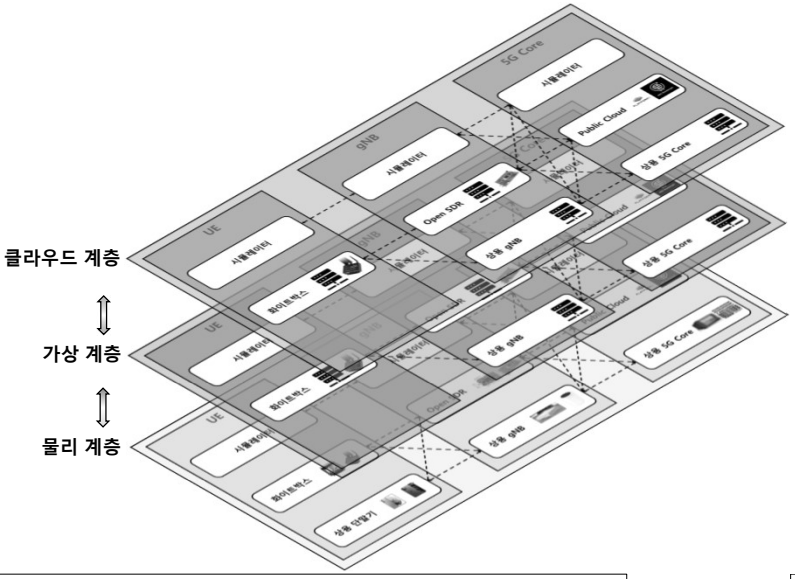
DAY 2: ENHANCED MOBILE BROADBAND

❖ 5G 클라우드화 아키텍처

- 물리 계층
- 가상화 계층
- 클라우드화 계층

네트워크 보안	• 모든 네트워크 기능을 포함하는 보안 (물리, 가상, 컨테이너)
애플리케이션 보안	• 5G 네트워크 상에 동작하는 서비스와 애플리케이션의 보안
물리적 보안	• 하드웨어, 셀 사이트, PoP 보안



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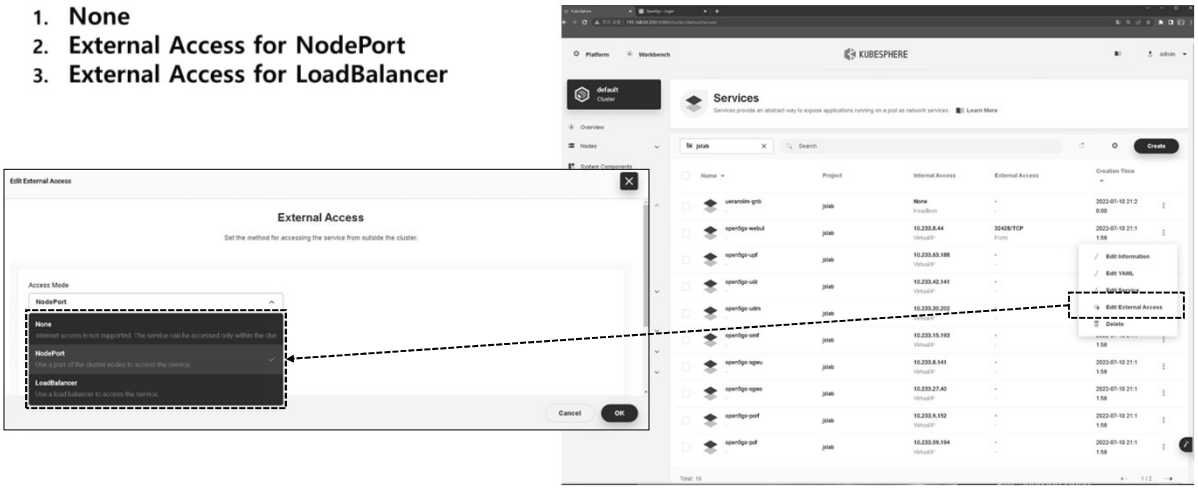
DAY 2: ENHANCED MOBILE BROADBAND

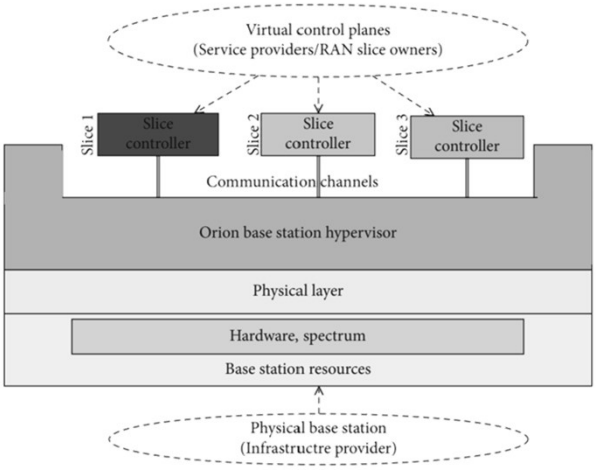
❖ Deploying 5G core network on Kubernetes: 포트 노출 정책

1. None
2. External Access for NodePort
3. External Access for LoadBalancer



DAY 2: ENHANCED MOBILE BROADBAND

❖ High level of Orion testbed architecture

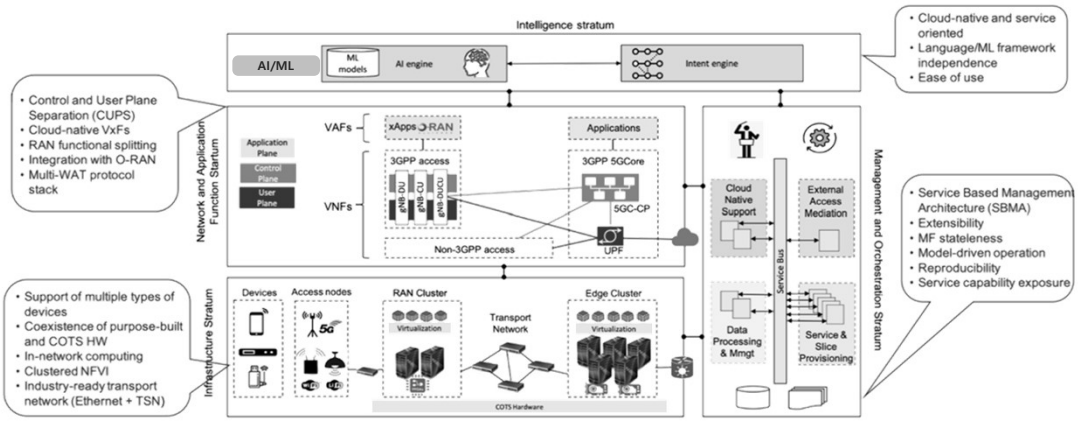


Wireless Communications and Mobile Computing, Volume 2021, Article ID 6655216, 26 pages, https://doi.org/10.1155/2021/6655216

DAY 2: ENHANCED MOBILE BROADBAND

❖ **5G-CLARITY proposed architecture**

• **5G-CLARITY system architecture**



Source: 5G-CLARITY [H2020-871428], Mir Ghoraishi(GIGASYS)