5G Radio

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JS Lab

5G 융합서비스 테스트베드

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I. 3GPP 5G 요구사항과 표준화
II. NR introduction
III. NR Physical layer & MAC
IV. mmWave 5G Applications

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I. 3GPP 5G 요구사항과 표준화

- 5G 목표와 비전
- 5G 표준의 발전

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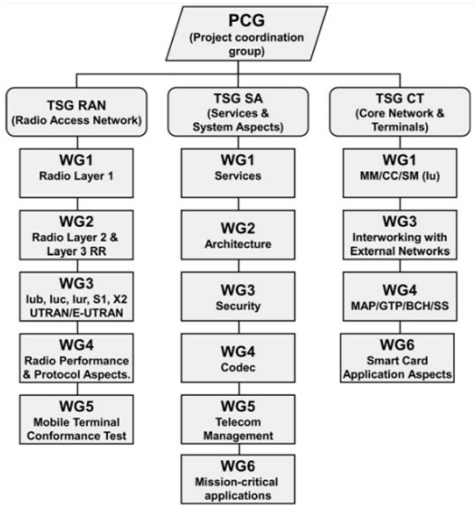
I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ 3GPP 구성



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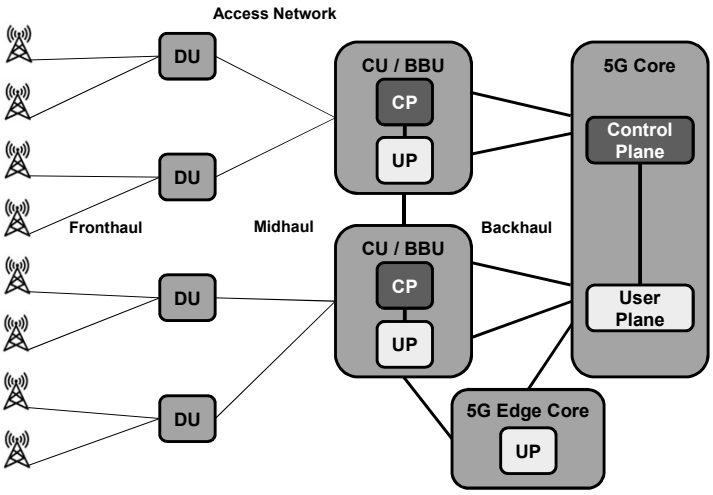
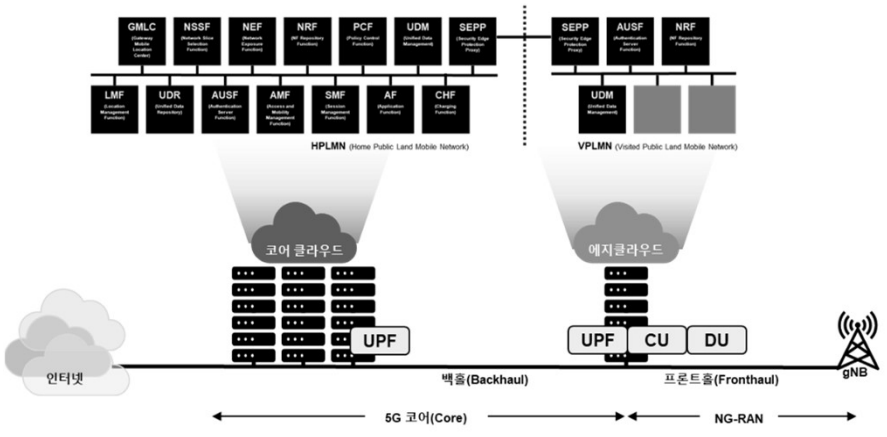
I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ 5G Network Architecture (예)



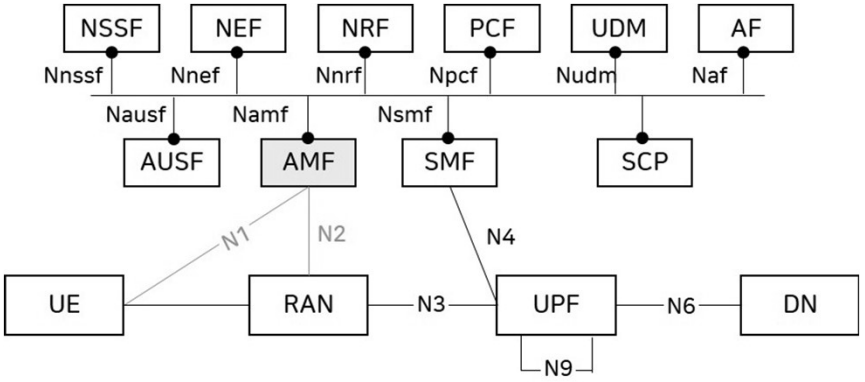
I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ 5G SA (Standalone) 표준



I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ SBI 기반의 5G 시스템 구조



(출처: http://terms.tta.or.kr/dictionary/dictionaryView.do?word_seq=170480-6)

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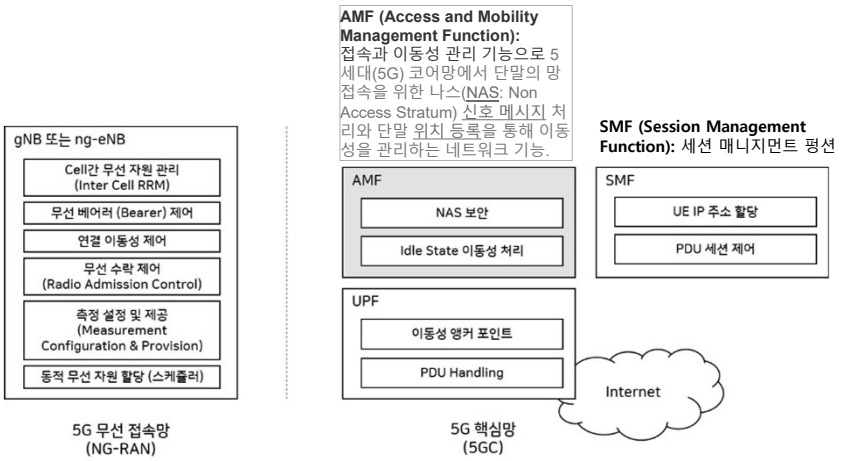
1. 5G 목표와 비전

❖ SBI 기반의 5G 시스템 구조



(출처: http://terms.tta.or.kr/dictionary/dictionaryView.do?word_seq=170480-6)

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1. 5G 목표와 비전

❖ 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	-	-	-

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1. 5G 목표와 비전

❖ 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

(* US FCC Nov. 2019. US FCC FNPRM Oct. 28 2020 will be explained later session.)

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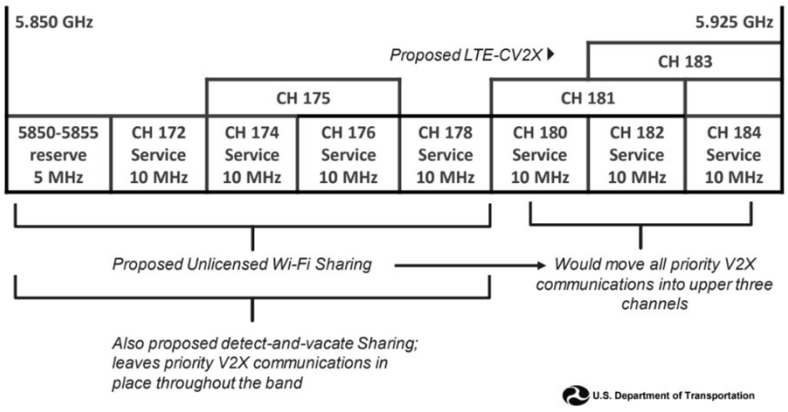
I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

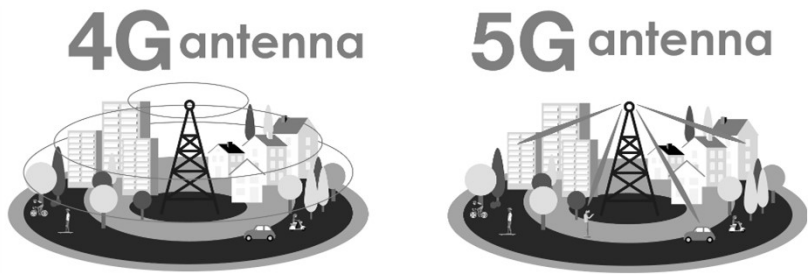
❖ US 5G NR V2X case



I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ 5G는 더 큰 대역폭의 스펙트럼을 사용

❖ 5G 안테나는 빔포밍 기술을 이용하여 동일 주파수를 반복 사용하며 무선 대역폭을 확대



(출처: https://radio-waves.orange.com/en/radio-networks-and-antennas/5g/)

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

I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ 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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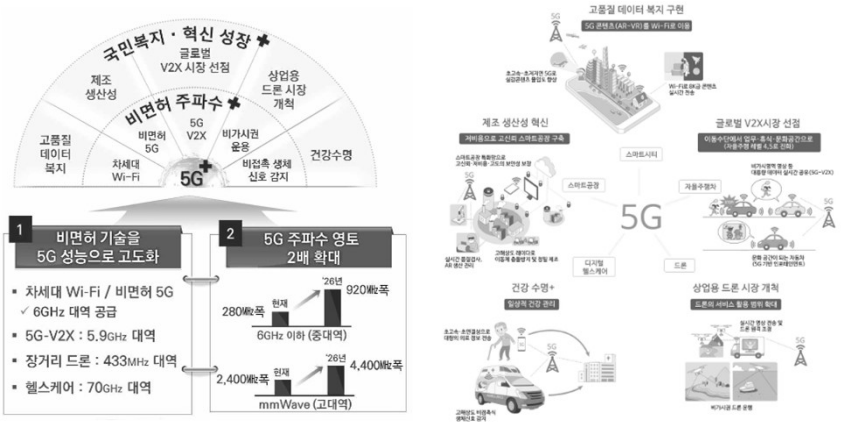
I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ 비면허 주파수 기술과 서비스

❖ 5G와 결합·보조하는 비면허 기술을 5G 성능으로 고도화 전략



(출처: 5G+ 스펙트럼 플랜, 과학기술정보통신부)

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I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ 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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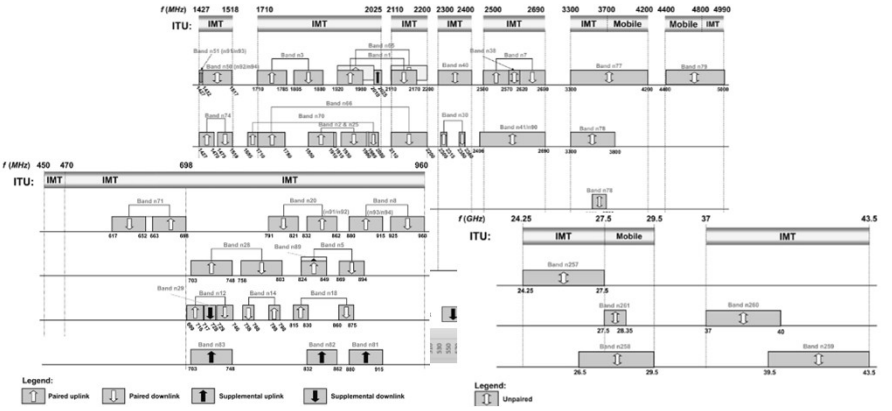
1. 5G 목표와 비전

❖ NR 주파수

- Frequency range 1 (FR1): 410–7125 MHz. — 450 MHz – 6000 MHz (Rel. 15)
- Frequency range 2 (FR2): 24.25–52.6 GHz. — 52.6 GHz – 71 GHz (Rel. 17 ?)



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

I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ NR 주파수

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

Shared 5.9 GHz – 7.1GHz (미국, 한국)
5.9 GHz – 6.4GHz (EU)

NR Band	Uplink Range (MHz)	Downlink Range (MHz)	Duplex Mode	Main Region(s)
n1	1920–1980	2110–2170	FDD	Europe, Asia
n2	1850–1910	1930–1990	FDD	Americas (Asia)
n3	1710–1785	1805–1880	FDD	Europe, Asia (American)
n5	824–849	869–894	FDD	Americas, Asia
n7	2500–2570	2620–2690	FDD	Europe, Asia
n8	880–915	925–960	FDD	Europe, Asia
n12	699–716	729–746	FDD	US
n14	788–798	758–768	FDD	US
n18	815–830	860–875	FDD	Japan
n20	832–862	791–821	FDD	Europe
n25	1850–1915	1930–1995	FDD	Americas
n28	703 - 748	758 - 803	FDD	Asia/Pacific
n29	N/A	717–728	N/A	Americas
n30	2305–2315	2350–2360	FDD	Americas
n34	2010–2025	2010–2025	TDD	Asia
n38	2570–2620	2570–2620	TDD	Europe
n39	1880–1920	1880–1920	TDD	China
n40	2300–2400	2300–2400	TDD	Europe, Asia
n41	2496–2690	2496–2690	TDD	US, China
n48	3550–3700	3550–3700	TDD	US
n50	1432–1517	1432–1517	TDD	Europe
n51	1427–1432	1427–1432	TDD	Europe
n65	1920–2010	2110–2200	FDD	Europe
n66	1710–1780	2110–2200	FDD	Americas
n70	1695–1710	1995–2020	FDD	Americas
n71	663–698	617–652	FDD	Americas
n74	1427–1470	1475–1518	FDD	Japan

n1(B1)
n3(B3)
n5(B5)
n7(B7)
re-farming carriers from LTE to NR
DSS(Dynamic spectrum sharing)
SDL
SUL
n78

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

I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ NR 주파수

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

Shared 28.9GHz-29.5GHz(한국)

n257

NR Band	Uplink and Downlink Range (MHz)	Duplex Mode	Main Region(s)
n257	26500–29500	TDD	Asia, Americas (global)
n258	24250–27500	TDD	Europe, Asia (global)
n259	39500–43500	TDD	Global
n260	37000–40000	TDD	Americas (global)
n261	27500–28350	TDD	Americas

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

I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ Core Network Architecture Evolution in 5G

- Functional entities
- Single Core
- Dedicated protocols

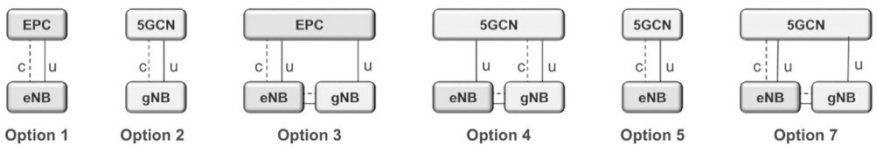
5G

- Service Based (SBA/SBI/NAPS)
- Virtualization & Slicing
- Softwarization/ Cloudification
- Application Programming Interfaces
- Harmonized protocols (HTTP …)
- Exposure to 3rdParties
- Backward & Forward Compatibility

(출처: Source: Georg Mayer)

I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ Different combinations of core networks and radio-access tech.

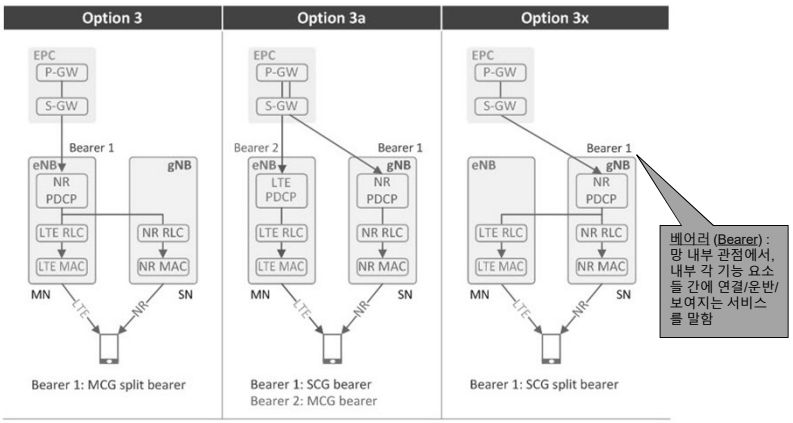


(출처: The Next Generation Wireless Access Technology Second, Edition Erik Dahlman Stefan Parkvall Johan Sköld)

I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ 현재 5G Phase 1의 Dual Connections (Option 3 case)

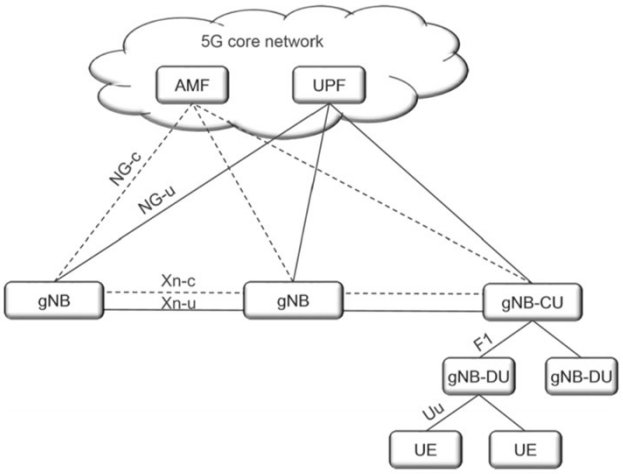
❖ NSA DC 구조는 LTE/NR 이중 연결 설정하여 사용자 트래픽을 결합



(출처: https://www.netmanias.com/ko/?m=view&id=blog&no=14392)

I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ Radio-access network interfaces.



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I. 3GPP 5G 요구사항과 표준화
1. 5G 목표와 비전

❖ 세계 각국의 Local 5G 주파수 현황

국가	5G/4G	대역폭	주파수 범위	상용화 현황	관련 정보	규제 기관
일본	5G 5G 5G	100MHz 200MHz 800MHz	28.2 - 28.3 GHz 4.6 - 4.8 GHz 28.3 - 29.1 GHz ※ 이동사는 사용 못함	2019.12.24 신청 개시 2020년말 할당예정 2020년말 할당예정	Local 5G 연 주파수 이용료 (28.2-28.3GHz) • Local 5G 기지국: 2,600엔/대/1년, Local 5G 단말: 370엔/대/1년 • 기업내 1개의 기지국과 100개의 단말을 설치하면 연 요금이 = 2,600엔 + 370엔x100대 = 39,600엔/년, 1년에 42만원, 1달에 3만 5천원	MIC (총무성)
독일	5G 5G	100MHz 1GHz	3.7 - 3.8 GHz 26.5 - 27.5 GHz	2019.11.21 신청 개시 Local 5G용으로 예약	10-Year License Fee [€] = 1000+100x10x5x(6x0.01)=1,300[€] (100MHz, 10년, 면적: 100m x 100m, 주거/교통 밀집지역). 1년에 130유로 (17만원), 한달에 1만 7천원	BNetzA 신청사이트>>
미국	4G, 5G	150MHz	3.55 - 3.7 GHz ※ 이동사도 경매 참여	2020.07.23 CBRS PAL 경매 시작	• CBRS GAA(General Authorized Access): 2020년 1월 27일 상용화 (주파수 무료) • CBRS PAL(Priority Access License): 2020년 7월 23일 경매 시작 (현재, 348개 기업이 경매 참여 등록)	FCC
영국	5G 5G	390MHz 2.25GHz	3.8 - 4.2 GHz (in or out) 24.25 - 26.5 GHz (indoor only) ※ 이통사는 사용 못함	2019.12.09 신청 개시 "	Annual License Fee • 3.8~4.2 GHz: Low power license (지름 50미터의 면적, 원하는 만큼의 기지국 설치허용)의 경우 : 10MHz당 £80, 20 MHz = £160, 100 MHz = £800 • 26GHz밴드는 BW 무관히 £320	Ofcom 신청 사이트>>
홍콩	5G	400MHz	27.95 - 28.35 GHz	2019.07.15 신청 개시	Annual License Fee: 기본료 HK$100,000, 단말 100개당 HK$200, 기지국당 HK$1,000, 1KHz당 HK$1. 예: 단말 1,000개, 기지국 5대, 100MHz: HK$207,000/년 (약 3,200만원/년)	OFCA 신청사이트>>
핀란드	4G 5G	20MHz 850MHz	2.3 - 2.32 GHz 24.25 - 25.1 GHz	2020.06.15 신청 개시 Local 5G용으로 예약	20MHz, 기지국 1대, 단말 30개: €984/년, 20MHz, 기지국 6대, 단말 100+개: €4,508/년	Traficom 신청사이트>>
칠레	5G	50MHz	3.75 - 3.8 GHz	Local 5G용으로 예약		SUBTEL
말레이지아	5G	1.6GHz	26.5 - 28.1 GHz	Local 5G용으로 예약		MCMC
프랑스	4G 5G	40MHz	2.575 - 2.615 GHz	2019.05.09 신청 개시		Arcep
스웨덴	5G 5G	80MHz 850MHz	3.72 - 3.8 GHz 24.25 - 25.1 GHz	Local 5G용으로 예약 Local 5G용으로 예약		PTS
호주	5G	TBD	24.25 - 27.5 GHz	Local 5G용으로 예약		AMCA
룩셈부르크	5G	100MHz	3.7 - 3.8 GHz	Local 5G용으로 예약		SMC

(출처: 넷매니아즈)

- Private 5G란 5G 기술과 여타의 통신기술 및 시스템이 통합되어 특정 구역 내에서 서비스 및 통신을 제공하는 LAN
- Private 5G는 local 5G, 5G LAN(Local Area Network), enterprise 5G, non-public 5G 등 다양한 용어로 사용

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I. 3GPP 5G 요구사항과 표준화
2. 5G 표준의 발전

❖ 6G Technologies (NTT Docomo 예)

❖ 5G 기반 Killer Service Reference의 발전 방향

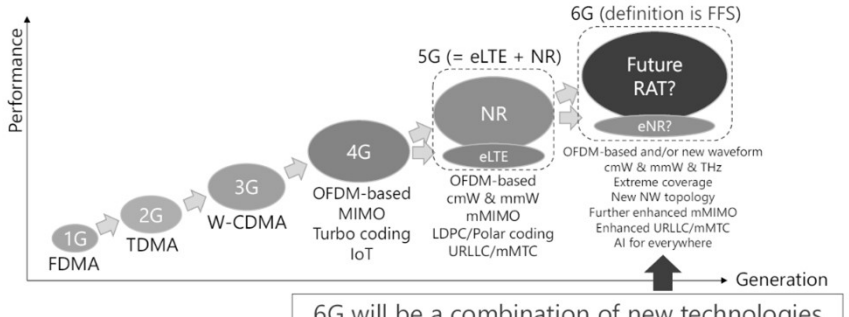

Figure 4-1. Technological evolution up to 6G in mobile communications

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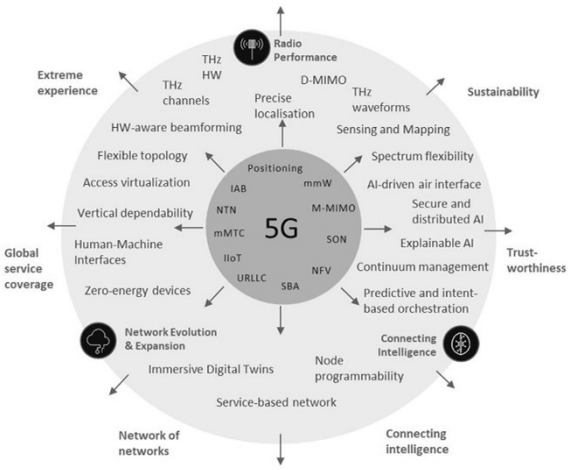
I. 3GPP 5G 요구사항과 표준화
2. 5G 표준의 발전

❖ 5G 기반 Killer Service Use Case의 Technical Gap (6G에서 해결)



Source: https://hexa-x.eu/research/hexa-x-the-joint-european-initiative-to-shape-6g/

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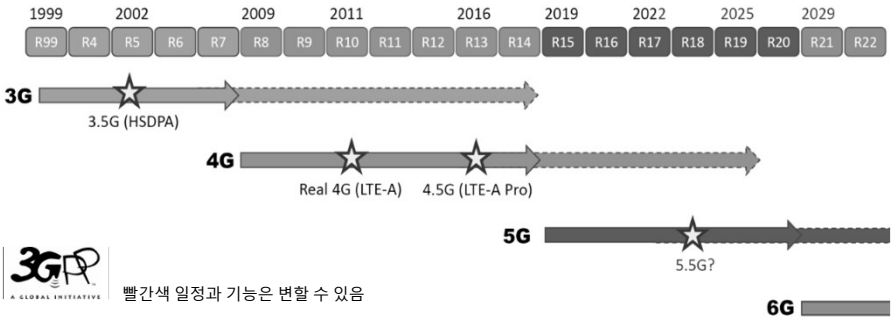
5G 융합서비스 테스트베드
james@jslab.kr

I. 3GPP 5G 요구사항과 표준화
2. 5G 표준의 발전

❖ 대역폭 확대: Cband(~100MHz) / mmWave(~400MHz)

❖ 새로운 공중 인터페이스: f-OFDM, Polar Code, LDPC, UL & DL 분리

❖ Massive MIMO



빨간색 일정과 기능은 변할 수 있음

- MIMO (Multiple-input multiple-output): 다중 경로 전파를 이용하기 위해 다중 송신 및 수신 안테나를 사용하여 무선 링크의 용량을 증가하는 방법.

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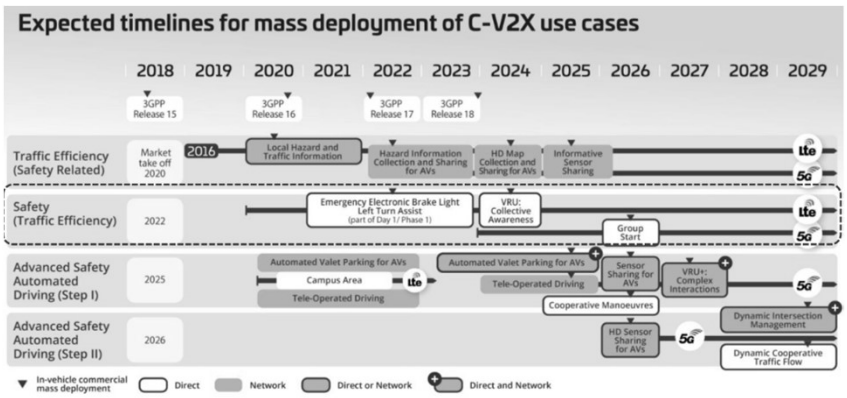
I. 3GPP 5G 요구사항과 표준화
2. 5G 표준의 발전

❖ 5GAA 2030 Roadmap for C-V2X



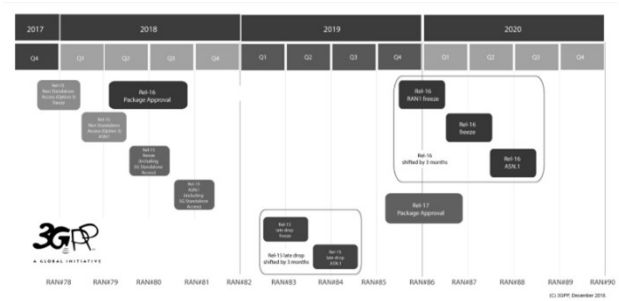
Sources from 5GAA(https://5gaa.org/)

I. 3GPP 5G 요구사항과 표준화
2. 5G 표준의 발전

❖ Release 15

3GPP Release 15

- NR
- The 5G System – Phase 1
- Massive MTC and Internet of Things (IoT)
- Vehicle-to-Everything Communications (V2x) Phase 2
- Mission Critical (MC) interworking with legacy systems
- WLAN and unlicensed spectrum use
- Slicing – logical end-2-end networks
- API Exposure – 3rd party access to 5G services
- Service Based Architecture (SBA)
- Further LTE improvements
- Mobile Communication System for Railways (FRMCS)



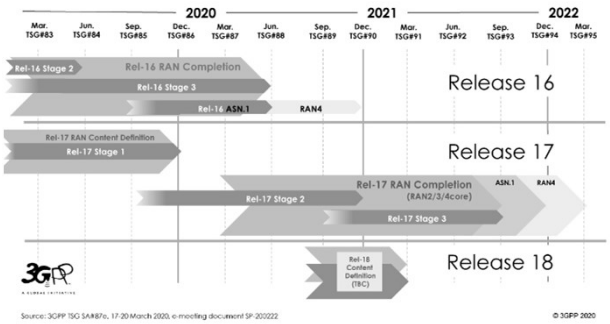
- https://www.3gpp.org/release-15

I. 3GPP 5G 요구사항과 표준화
2. 5G 표준의 발전

❖ Release 16

Release 16

- **The 5G System – Phase 2**
- **V2x Phase 3:** Platooning, extended sensors, automated driving, remote driving
- **Industrial IoT**
- **Ultra-Reliable and Low Latency Communication (URLLC) enh.**
- **NR-based access to unlicensed spectrum (NR-U)**
- **5G Efficiency:** Interference Mitigation, SON, eMIMO, Location and positioning, Power Consumption, eDual Connectivity, Device capabilities exchange, Mobility enhancements
- **Integrated Access and Backhaul (IAB)**
- **Enh. Common API Framework for 3GPP Northbound APIs (eCAPIF)**
- **Satellite Access in 5G**
- **Mobile Communication System for Railways (FRMCS Phase 2)**



- https://www.3gpp.org/release-16

I. 3GPP 5G 요구사항과 표준화
2. 5G 표준의 발전

❖ Release 17

Release 17

- **NR MIMO**
- **NR Sidelink enh.**
- **52.6 - 71 GHz with existing waveform**
- **Dynamic Spectrum Sharing (DSS) enh.**
- **Industrial IoT / URLLC enh.**
- **Study - IoT over Non Terrestrial Networks (NTN)**
- **NR over Non Terrestrial Networks (NTN)**
- **NR Positioning enh.**
- **Low complexity NR devices**
- **Power saving**
- **NR Coverage enh.**
- **Study - NR eXtended Reality (XR)**
- **NB-IoT and LTE-MTC enh.**
- **5G Multicast broadcast**
- **Multi-Radio DCCA enh.**
- **Multi SIM**
- **Integrated Access and Backhaul (IAB) enh.**
- **NR Sidelink relay**
- **RAN Slicing**
- **Enh. for small data**
- **SON / Minimization of drive tests (MDT) enh.**
- **NR Quality of Experience**
- **eNB architecture evolution, LTE C-plane / U-plane split**
- **Satellite components in the 5G architecture**
- **Non-Public Networks enh.**
- **Network Automation for 5G - phase 2**
- **Edge Computing in 5GC**
- **Proximity based Services in 5GS**
- **Network Slicing Phase 2**
- **Enh. V2x Services**
- **Advanced Interactive Services**
- **Access Traffic Steering, Switch and Splitting support in the 5G system architecture**
- **Unmanned Aerial Systems**
- **5GC LoCation Services**
- **Multimedia Priority Service (MPS)**
- **5G Wireless and Wireline Convergence**
- **5G LAN-type services**
- **User Plane Function (UPF) enh. for control and 5G Service Based Architecture (SBA)**

These are some of the Rel-17 headline features, prioritized during the December 2019 Plenaries (TSG#86)

Start of work: January 2020

Full details of the content of Rel-17 are in the Work Plan: www.3gpp.org/specifications/work-plan

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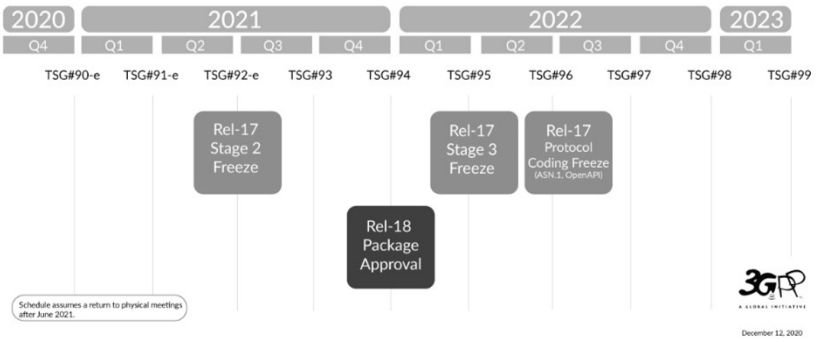
- https://www.3gpp.org/release-17

I. 3GPP 5G 요구사항과 표준화
2. 5G 표준의 발전

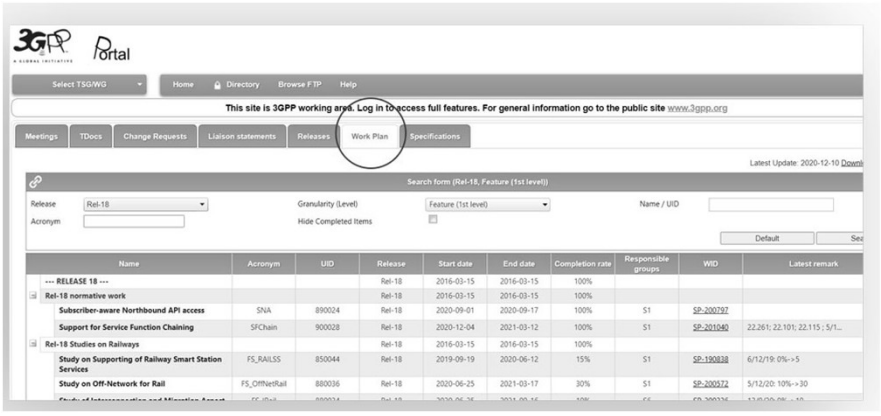
❖ Release 17



- https://www.3gpp.org/release-17

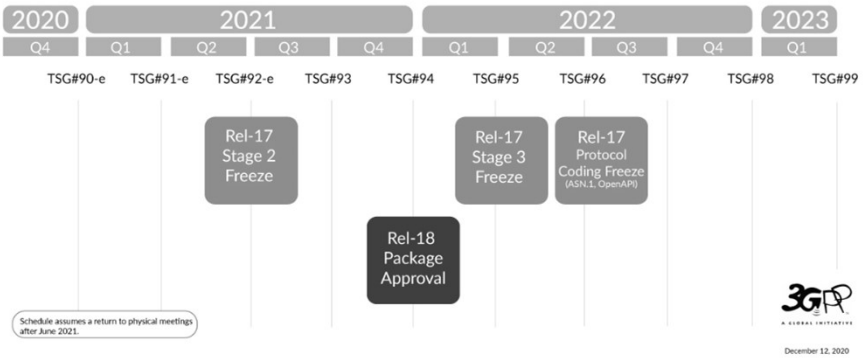
I. 3GPP 5G 요구사항과 표준화
2. 5G 표준의 발전

❖ Release 18



I. 3GPP 5G 요구사항과 표준화
2. 5G 표준의 발전

❖ **Release 18**



I. 3GPP 5G 요구사항과 표준화
2. 5G 표준의 발전

❖ **5G NR enhancements for mmWave**

Completed Release 16 Projects

- **Integrated access and backhaul (IAB)**
  Enabling flexible deployment of small cells reusing spectrum and equipment for access and backhaul
- **Enhanced beam management**
  Improving latency, robustness and performance with full beam refinement and multi-antenna-panel beam support
- **Power saving features**
  Maximizing device sleep duration to improve power consumption as well as allowing faster link feedback
- **Dual connectivity optimization**
  Reducing device initial access latency and improving coverage when connected to multiple nodes
- **Positioning**
  Meeting initial accuracy requirements of 3m (indoor) to 10m (outdoors) for 80% of time

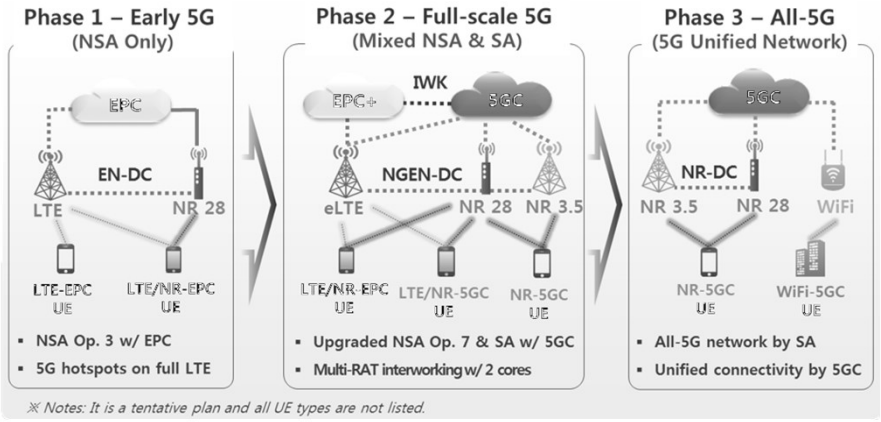
Release 17+ Projects

- **Improved IAB for distributed deployment**
  Introducing full duplex operations and mobile relays for improved capability, coverage, and QoS
- **Optimized coverage & beam management**
  Reducing overhead, enhancing performance (e.g., beam selection), improving coverage
- **Expanded spectrum support**
  Supporting licensed and unlicensed spectrum in frequencies ranging from 52.6 GHz to 71 GHz
- **New use cases beyond eMBB**
  Expanding mmWave support for sidelink, URLLC, and industrial IoT use cases (e.g., NR-Light)
- **Enhanced positioning**
  Enhancing capability for a wide range of use cases – cm-level accuracy, lower latency, higher capacity

Qualcomm

I. 3GPP 5G 요구사항과 표준화
2. 5G 표준의 발전

❖ 5G 비단독 표준(NSA) 에서 단독(SA) 표준으로 단계별 이전



(출처: KT's 5G Network Migration Plan)

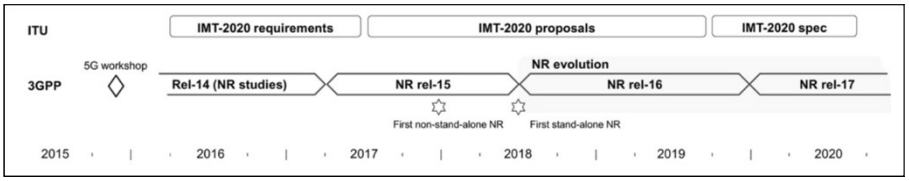
II. NR introduction

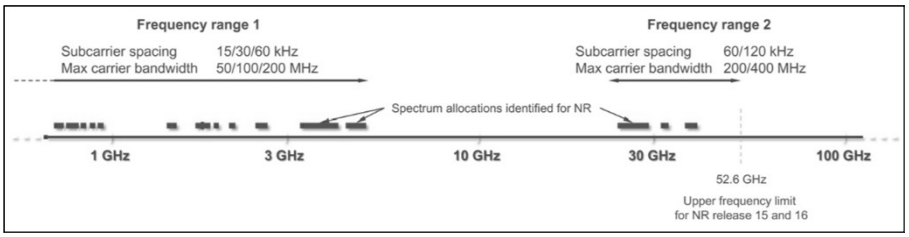
- 구성 및 동작원리
- 빔포밍 (Beamforming)

II. NR introduction
1. 구성 및 동작 원리

❖ FDD vs. TDD

- 3GPP Timeline
- Spectrum identified for NR and corresponding subcarrier spacings.



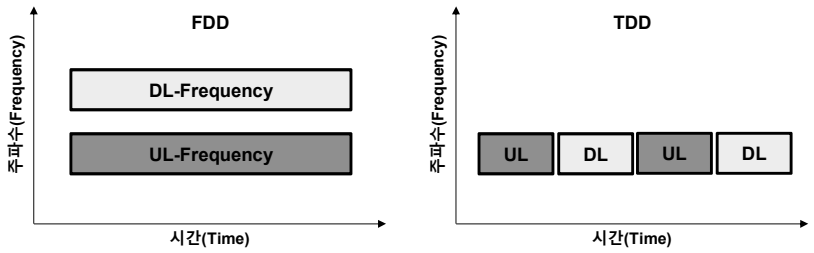


(출처: The Next Generation Wireless Access Technology Second, Edition Erik Dahlman Stefan Parkvall Johan Sköld)

II. NR introduction
1. 구성 및 동작 원리

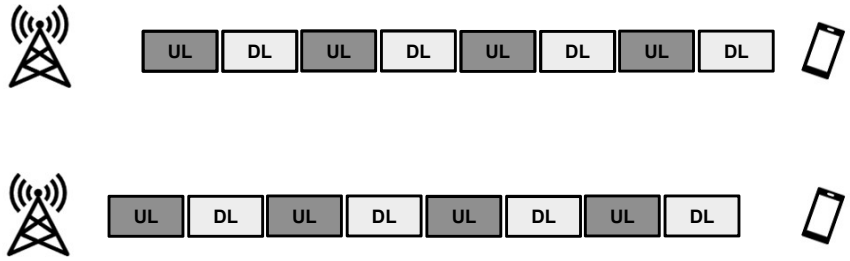
❖ FDD vs. TDD

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



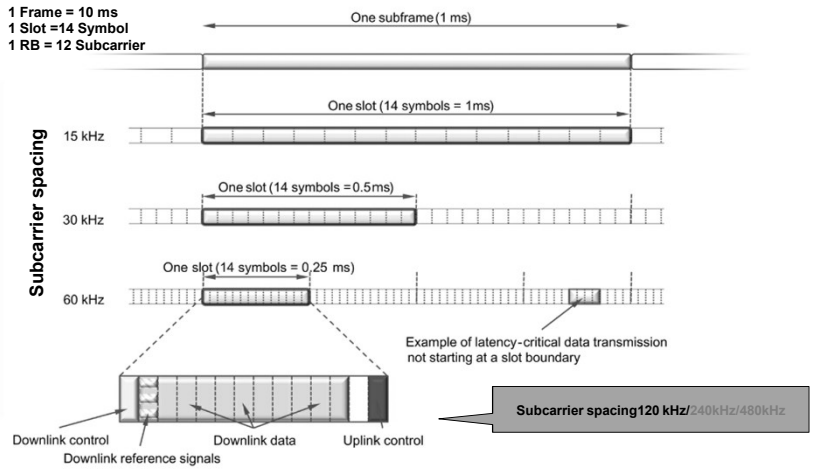
II. NR introduction
1. 구성 및 동작 원리

❖ TDD를 위한 동기화 고려



II. NR introduction
1. 구성 및 동작 원리

❖ Synchronization for TDD

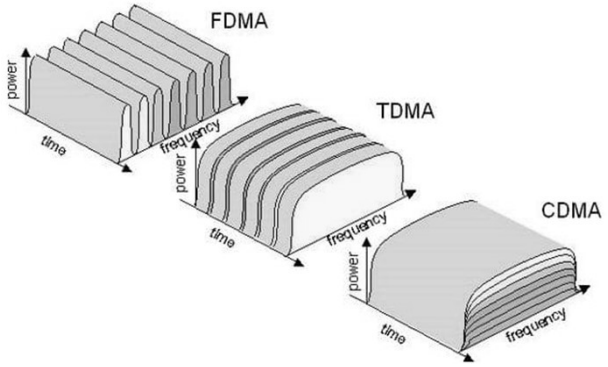


(출처: The Next Generation Wireless Access Technology Second, Edition Erik Dahlman Stefan Parkvall Johan Sköld)

II. NR introduction
1. 구성 및 동작 원리

❖ 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)



(출처: https://networkencyclopedia.com/code-division-multiple-access-cdma/)

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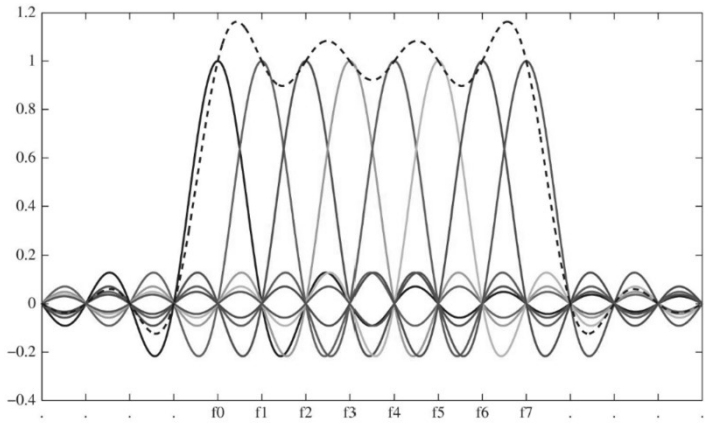
II. NR introduction
1. 구성 및 동작 원리

❖ Waveforms and Mixed-Numerology

❖ Spectrum of OFDM signals with , depicted by the dashed line.



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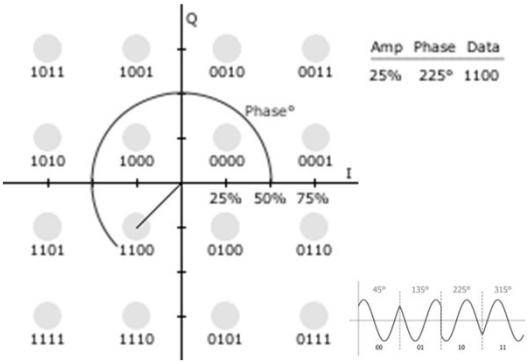
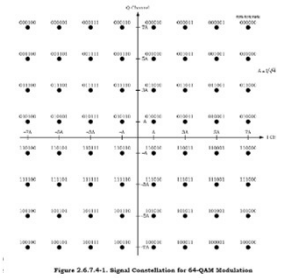
II. NR introduction
1. 구성 및 동작 원리

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

16-QAM의 constellation (예)



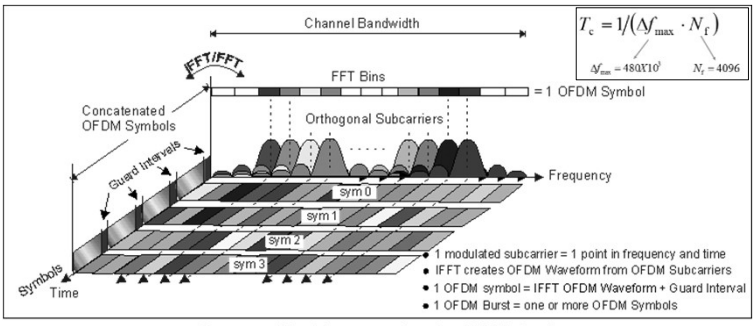
64-QAM의 constellation (예)



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

II. NR introduction
1. 구성 및 동작 원리

- ❖ OFDM
  - 직교 주파수 분할 다중 방식(Orthogonal frequency-division multiplexing, OFDM)은 다중 반송파(multiple carrier frequencies)를 이용하여 디지털 데이터를 인코딩하는 방식

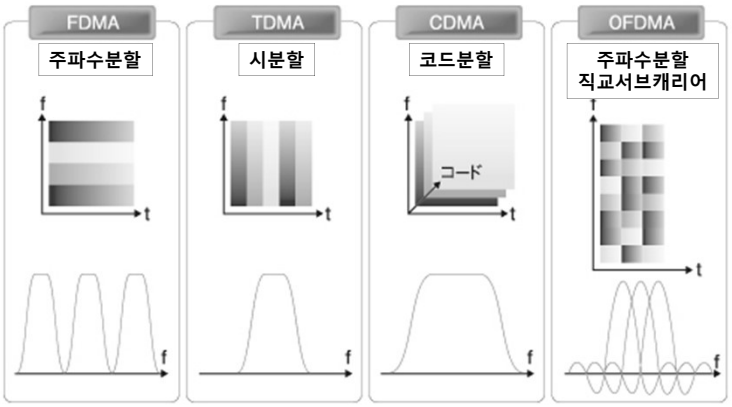


Frequency-Time Representative of an OFDM signal

(출처: http://rfmw.em.keysight.com/wireless/helpfiles/89600B/WebHelp/Subsystems/wlan-ofdm/content/ofdm_basicprinciplesoverview.htm)

II. NR introduction
1. 구성 및 동작 원리

❖ FDMA, TDMA, CDMA, OFDMA



(출처: https://www.atmarkit.co.jp/ait/articles/1005/13/news092.html)

II. NR introduction
1. 구성 및 동작 원리

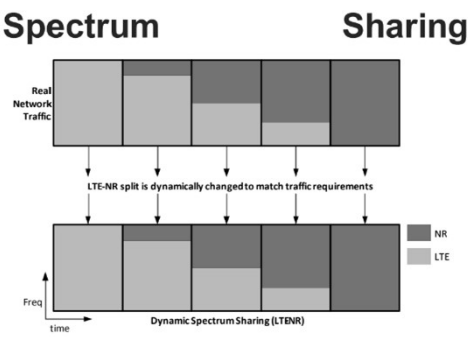
❖ Dynamic Spectrum Sharing

Dynamic

"**Dynamic**" is the key

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

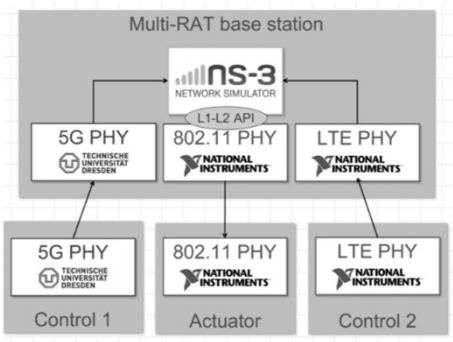
KEYSIGHT TECHNOLOGIES

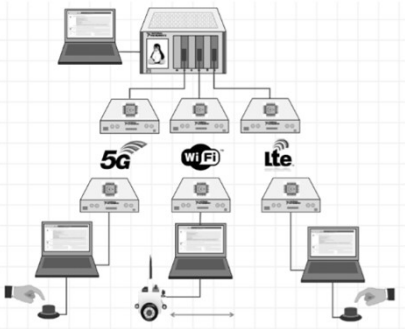


II. NR introduction
1. 구성 및 동작 원리

❖ 무선 계층의 추상화로 다양한 무선 기술 수용

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



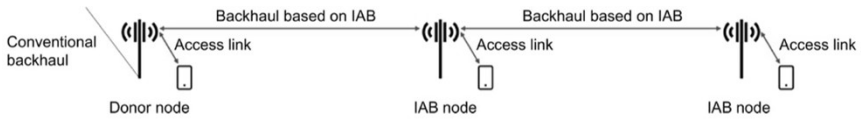


(출처: https://www.netmanias.com/ko/?m=view&id=oneshot&no=14450)

II. NR introduction
1. 구성 및 동작 원리

❖ Integrated Access and Backhaul

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

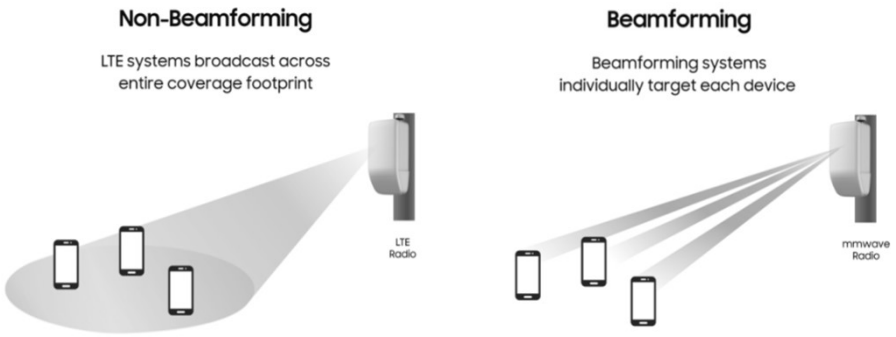


(출처: The Next Generation Wireless Access Technology Second, Edition Erik Dahlman Stefan Parkvall Johan Sköld)

II. NR introduction
2. 빔포밍 (Beamforming)

❖ 기존 안테나와 Beamforming 비교

❖ 빔포밍은 동일 주파수를 재사용하며 지향성으로 고속도 지원



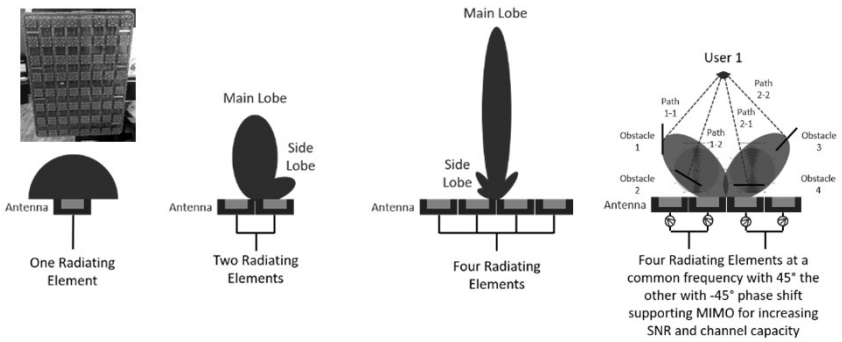
(출처: Case study: Orange Romania, Samsung)

▫ 빔포밍(Beamforming): 빔 스티어링은 모든 방사 요소에서 입력 신호의 위상을 변경함으로써 달성하며, 위상변조를 통해 신호가 특정 수신기를 대상으로 할 수 있음

II. NR introduction
2. 빔포밍 (Beamforming)

❖ 빔포밍 (What is 5G beamforming?)

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

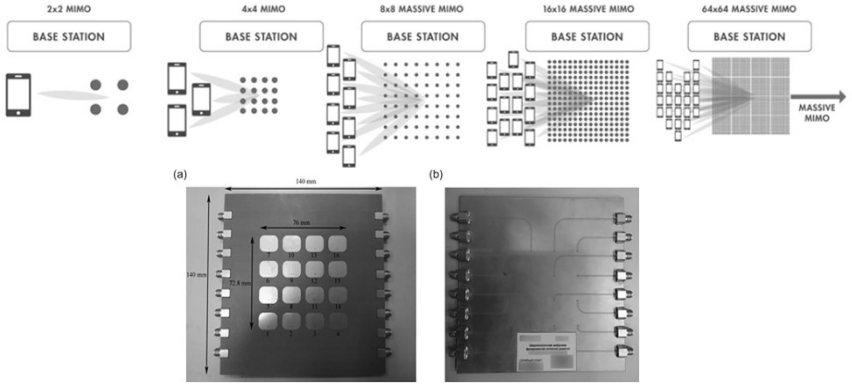


(출처: https://www.metaswitch.com/knowledge-center/reference/what-is-beamforming-beam-steering-and-beam-switching-with-massive-mimo)

II. NR introduction
2. 빔포밍 (Beamforming)

❖ Massive MIMO: 일반 주파수를 동시에 여러 방향으로 전송

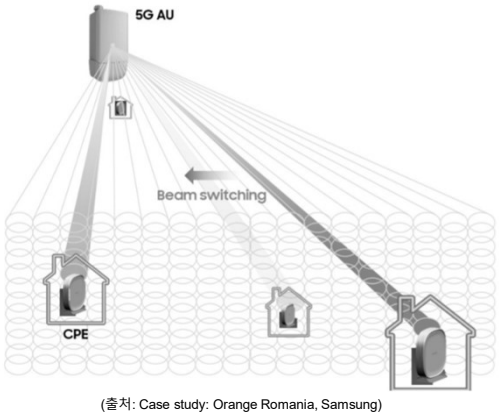
❖ 동일 주파수 중복 사용



출처: https://www.dolcera.com/web/blog/massive-mimo-a-boost-for-next-gen-5g-wireless-communication/

II. NR introduction
2. 빔포밍 (Beamforming)

❖ **빔스위칭 (Beam switching):** 무선 시스템은 범위 제한을 극복하기 위해 이들 대상 중 몇 개를 동시에 대상으로 할 수 있으며, 전체적으로 무선 에너지에 초점을 맞추며, 전체 그리드를 커버하기 위해 스케줄링 알고리즘에 따라 빔이 각 장치 사이를 빠르게 전환



(출처: Case study: Orange Romania, Samsung)

5G 융합서비스 테스트베드

james@jslab.kr

III. NR Physical layer & MAC

- NR Physical layer
- NR 프로토콜 구조

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5G 융합서비스 테스트베드

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III. NR Physical layer & MAC
1. NR Physical layer

❖LTE와 NR 시스템의 비교

구분	LTE	NR
주파수대역	6GHz 이하	6GHz 이하(FR1), 24.25GHz 이상(FR2)
대역폭	1.4, 3, 5, 10, 15, 20MHz	FR1: 5, 10, 15, …, 100MHz FR2: 50, 100, 200, 400MHz
부반송파간격	15kHz	FR1: 15, 30, 60kHz FR2: 60, 120, [240]kHz
TTI	1ms	1, 0.5, 0.25, 0.125ms 2, 4 and 7 symbols(tens us)
프레임구조	Type 1: FDD Type 2: TDD	Unified framework of FDD/TDD with bi-directional slot
MIMO	Up to 4 layers 다양한 전송모드 (OL/CL-MIMO SFBC, SM)	Up to 8 layers 단일전송모드(LTE TM9 유사) Multi-beam operation
참조신호 (Reference Signaling)	CRS, CSI-RS, SRS, DMRS	DMRS, CSI-RS(for BM, tracking, mobility, CSI), SRS, PTRS
채널코딩	Turbo Coding, TBCC	LDPC, Polar Code
Waveform	DL: CP-OFDM UL: DFT-s-OFDM	DL: CP-OFDM UL: CP-OFDM + DFT-s-OFDM
Initial Access	단일 빔	다중빔 지원(SS블록, 다양한 PRACH 구조 지원)
지원 서비스	eMBB, IoT	eMBB, URLLC
광대역지원	반송파집성(CA)	광대역 Carrier, BWP

출처: 김태중, 권종형, 김하성, 박병성, 육영수, 권기범, 이상욱, 이정훈, "3GPP 표준화 현황: Rel-15 규격 및 Rel-16 주요 이슈", 5G포럼 이슈리포트 Vol.6, 2018. 12.

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III. NR Physical layer & MAC
1. NR Physical layer

❖ 5G NR 기술

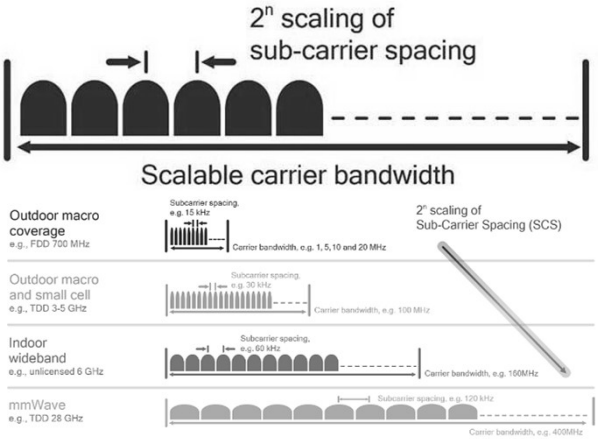
- OFDM (Orthogonal frequency-division multiplexing)
- Self-contained slot based framework
- Channel Coding
- MU-MIMO
- mmWave

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

III. NR Physical layer & MAC
1. NR Physical layer

❖ 5G NR 기술

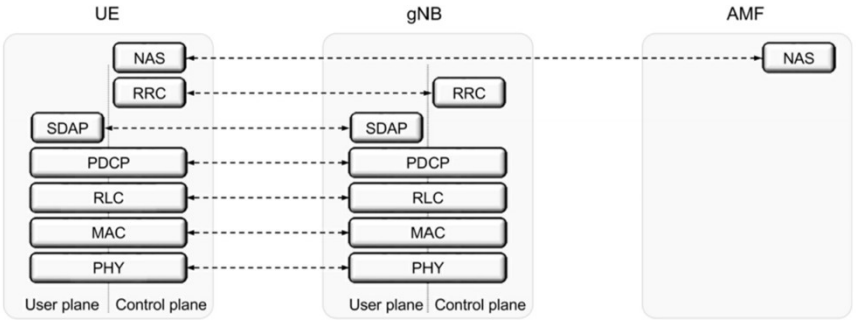
- OFDM 멀티톤 뉴머롤로지(Numerology)



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

III. NR Physical layer & MAC
2. NR 프로토콜 구조

❖ User-plane and control-plane protocol stack.



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

III. NR Physical layer & MAC
2. NR 프로토콜 구조

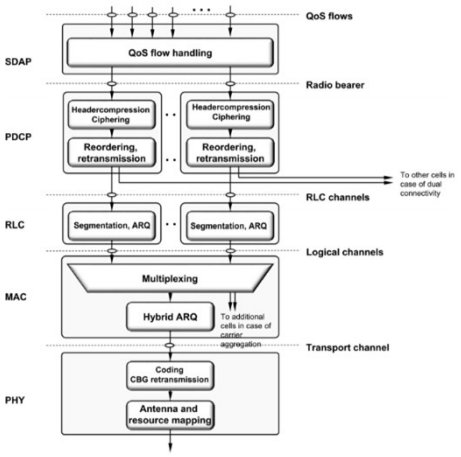
❖ NR downlink user-plane protocol architecture as seen from the device.

SDAP (Service Data Adaptation Protocol)

PDCP (Packet-Data Convergence Protocol)

RLC (Radio-Link Control)

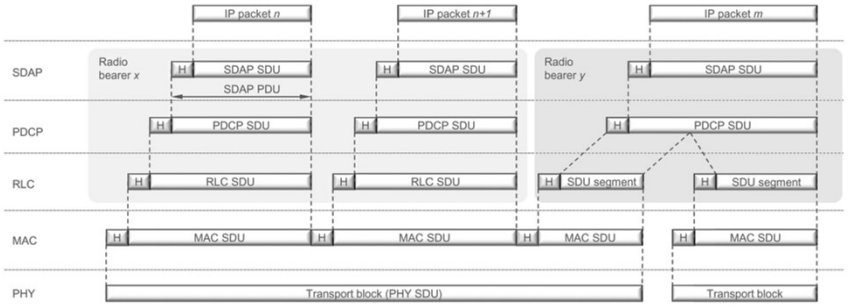
MAC (Medium-Access Control)



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

III. NR Physical layer & MAC
2. NR 프로토콜 구조

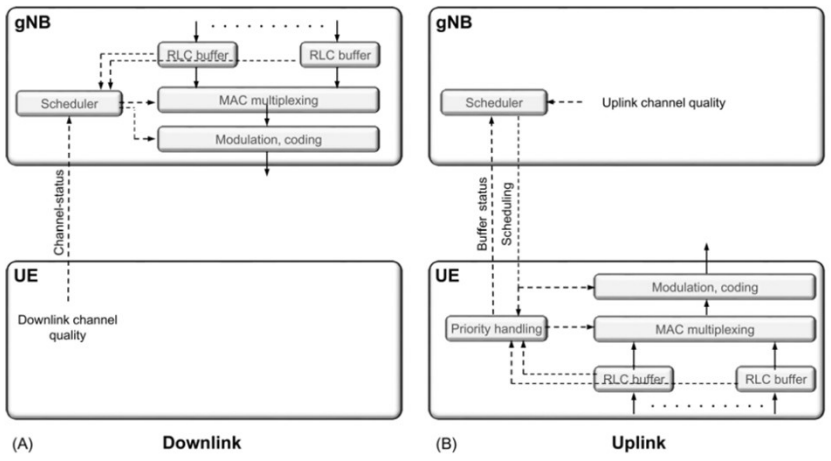
❖ Example of user-plane data flow.



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

III. NR Physical layer & MAC
2. NR 프로토콜 구조

❖ Transport-format selection

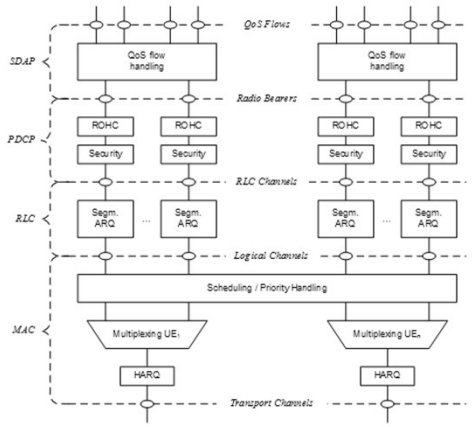


(출처: The Next Generation Wireless Access Technology Second, Edition Erik Dahlman Stefan Parkvall Johan Sköld)

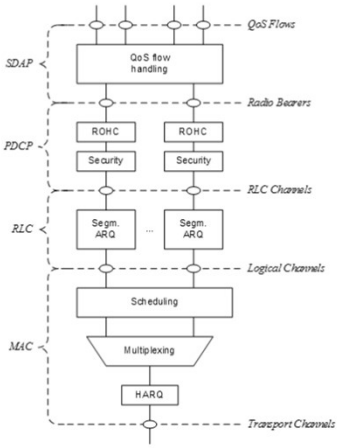
III. NR Physical layer & MAC
2. MAC

❖ Transport-format selection

Downlink Layer 2 Structure



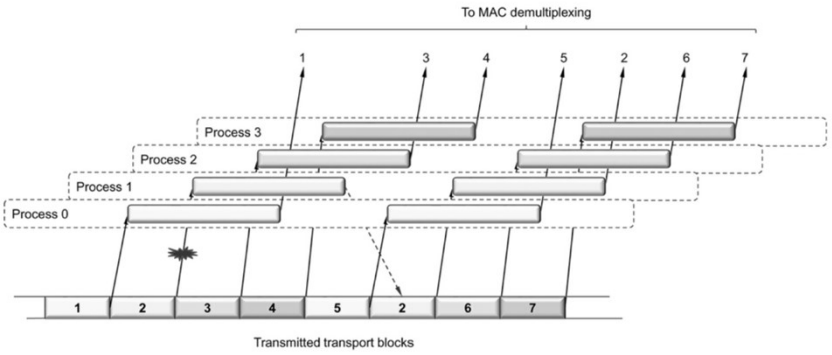
Uplink Layer 2 Structure



(출처: http://www.techplayon.com/5g-nr-radio-protocol-stack-layer-2-layer-3/)

III. NR Physical layer & MAC
2. NR 프로토콜 구조

❖ Multiple parallel hybrid-ARQ processes.



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

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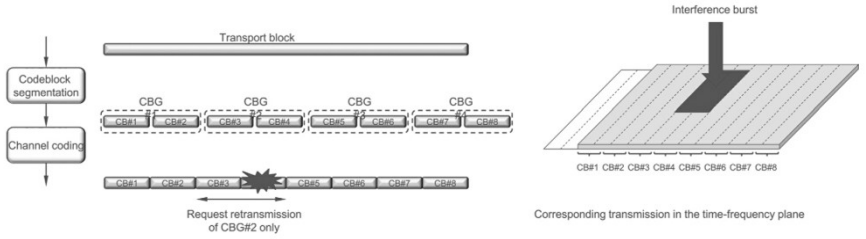
III. NR Physical layer & MAC
2. NR 프로토콜 구조

❖ Codeblock group retransmission.



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

III. NR Physical layer & MAC
3. MAC

❖ The main services and functions of the MAC sub layer include:

- Mapping between logical channels and transport channels
- Multiplexing/demultiplexing of MAC SDUs belonging to one or different logical channels into/from transport blocks (TB) delivered to/from the physical layer on transport channels
- Scheduling Information Reporting
- Error correction through HARQ
- Priority handling between UEs by means of dynamic scheduling
- Priority handling between logical channels of one UE by means of logical channel prioritization
- Padding

III. NR Physical layer & MAC
3. MAC

❖ 5G NR MAC Procedures

5G NR MAC Procedures	Description
Random Access Procedure	Get the initial uplink grant for UE and helps in performing synchronization with the gNB (i.e. network). It covers Random Access procedure initialization, Random Access Resource selection, Random Access Preamble transmission, Random Access Response reception, Contention Resolution and Completion of the Random Access procedure.
DL-SCH data transfer	It does everything needed to perform downlink data transfer.
UL-SCH data transfer	It does everything needed to perform uplink data transfer.
Scheduling request (SR)	It is used by UE to transmit request to gNB (i.e. network) to obtain UL grant.
PCH reception	It helps in monitoring paging message in special time period.
BCH reception	It carry basic informations regarding the 5G NR cell (e.g. MIB, SFN etc.).
DRX (Discontinuous Reception)	It helps in monitoring PDCCH as per special pattern in discontinuous manner. Due to this discontinuous monitoring, energy consumption can be achieved.
Other procedures	The other 5G NR MAC procedures include transmission and reception without dynamic scheduling, activation/deactivation of SCells, activation/deactivation of PDCP duplication, BWP (Bandwidth Part) operation, handling of measurement gaps, handling of MAC CEs, beam failure detection and recovery operation etc.

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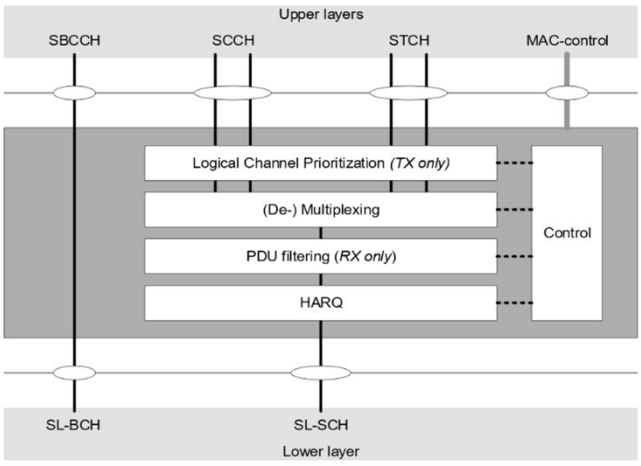
III. NR Physical layer & MAC
3. MAC

❖ 5G NR MAC Procedures



https://devopedia.org/5g-nr-channels

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IV. mmWave 5G Applications

- mmWave 모뎀/안테나
- Use Case

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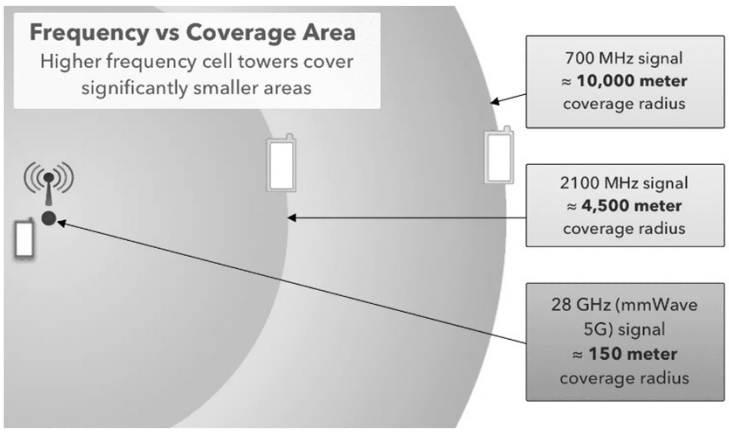
IV. mmWave 5G Applications
1. mmWave 모뎀/안테나

❖ Coverage



(출처: https://www.waveform.com/)

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IV. mmWave 5G Applications
1. mmWave 모뎀/안테나

- ❖ Advanced Thin-Profile Fan-Out with Beamforming Verification for 5G Wideband Antenna (ASE34)
- ❖ It has lower insertion loss as compared to FCBGA-based AiP.

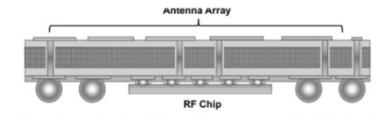


Fig.3. Cross-section view of the mmWave transceiver on flip chip ball grid array (FCBGA) AiP.

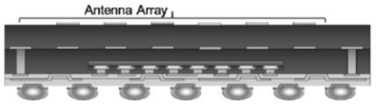
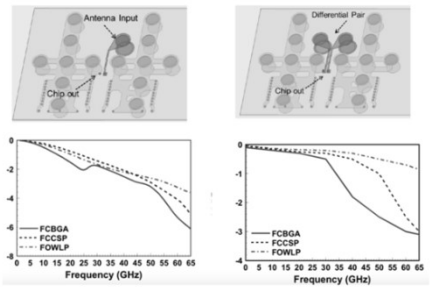


Fig. 8. Geometry of the fan-out Antenna in Package

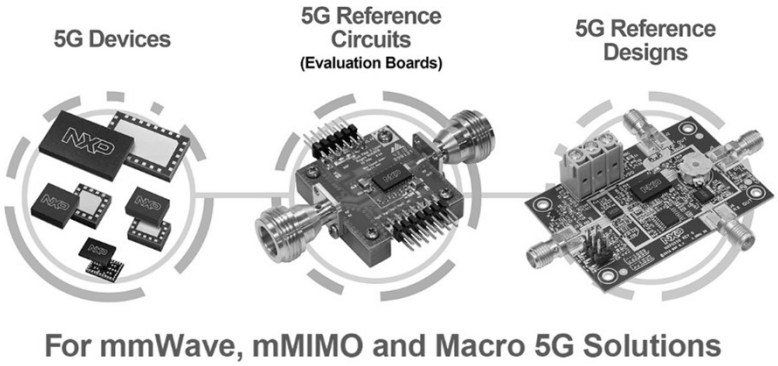


HIR
HETEROGENEOUS INTEGRATION ROADMAP

(출처: http://eps.ieee.org/hir)

IV. mmWave 5G Applications
1. mmWave 모뎀/안테나

- ❖ 5G Devices, Reference Circuits, Evaluation Boards and Reference Designs (예)

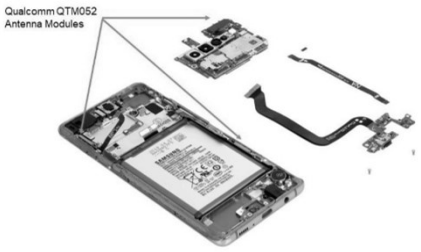


(출처: https://www.globenewswire.com/NewsRoom/AttachmentNg/bfed3649-45e6-404b-a489-94cdb3d2e423/en)

IV. mmWave 5G Applications
1. mmWave 모뎀/안테나

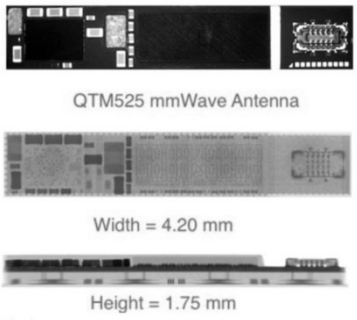
❖ 스마트폰의 mmWave

삼성전자 mmWave AiP 모듈



자료: OMDIA

Qualcomm mmWave 안테나 모듈

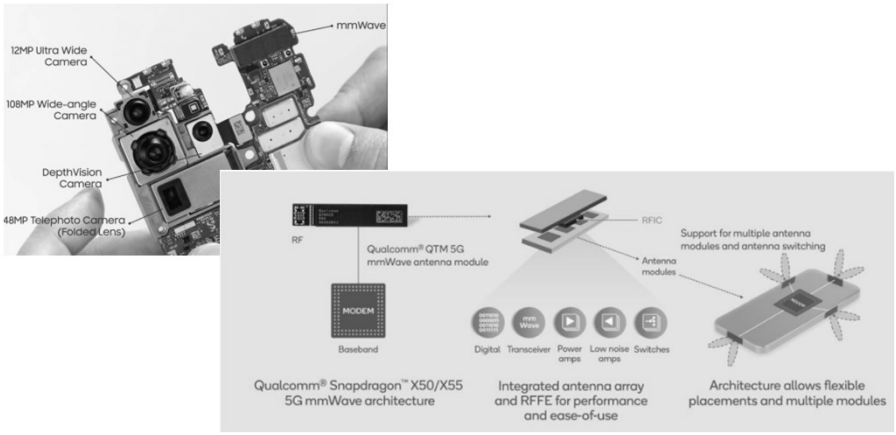


자료: Qualcomm

(출처: https://invest.kiwoom.com/inv/24207)

IV. mmWave 5G Applications
1. mmWave 모뎀/안테나

❖ mmWave 모뎀/안테나 모듈 구성



(출처: https://m.blog.naver.com/kas2724/221910469173 , 대신증권20200309f (mk.co.kr))

IV. mmWave 5G Applications
2. Use Case

❖ 28GHz용 Access Unit (AU)

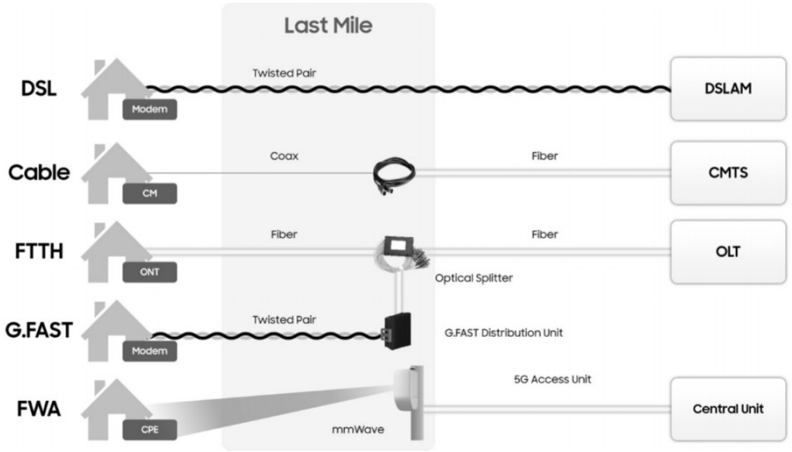
❖ 삼성전자(예): 약 10Kg 무게와 10L 부피이며 최대 용량은 10 Gbps.

Access Unit

출처: Case study: Orange Romania, Samsung

IV. mmWave 5G Applications
2. Use Case

❖ mmWave FWA(Fixed Wireless Access) 비교



(출처: Case study: Orange Romania, Samsung)

IV. mmWave 5G Applications
2. Use Case

❖ 무선 브로드밴드 (Wireless Broadband)

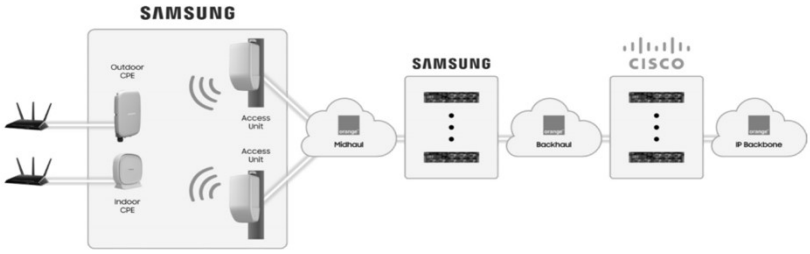
(출처: Case study: Orange Romania, Samsung)

IV. mmWave 5G Applications
2. Use Case

❖ 무선 브로드밴드 구성 (예): Orange Romania 5G FWA Friendly User Trial Architecture


Indoor CPE


Outdoor CPE

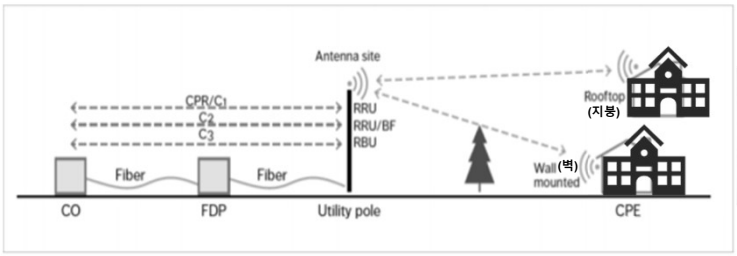


(출처: Case study: Orange Romania, Samsung)

IV. mmWave 5G Applications
2. Use Case

❖ **FWA, Beamforming 이용 시 구성(예)**

- 옥외용 CPE 사용시 5G 기지국 설치 필요 없는 구성
- 사내망의 유선 구성 및 일반 WiFi 기술 이용
- 5G 엣지 클라우드 컴퓨팅 응용 서비스



https://www.gsma.com/futurenetworks/5g/fixed-wireless-access-economic-potential-and-best-practices/

5G 융합서비스 테스트베드
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