4G vs. 5G Key Technology Differences

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CONTENT

RAN Structure	QoS	Radio Protocol Stack
Frame Structure	Physical Channel & Signals	Link Budget

RAN Structure: 4G ,5G NSA & 5G SA

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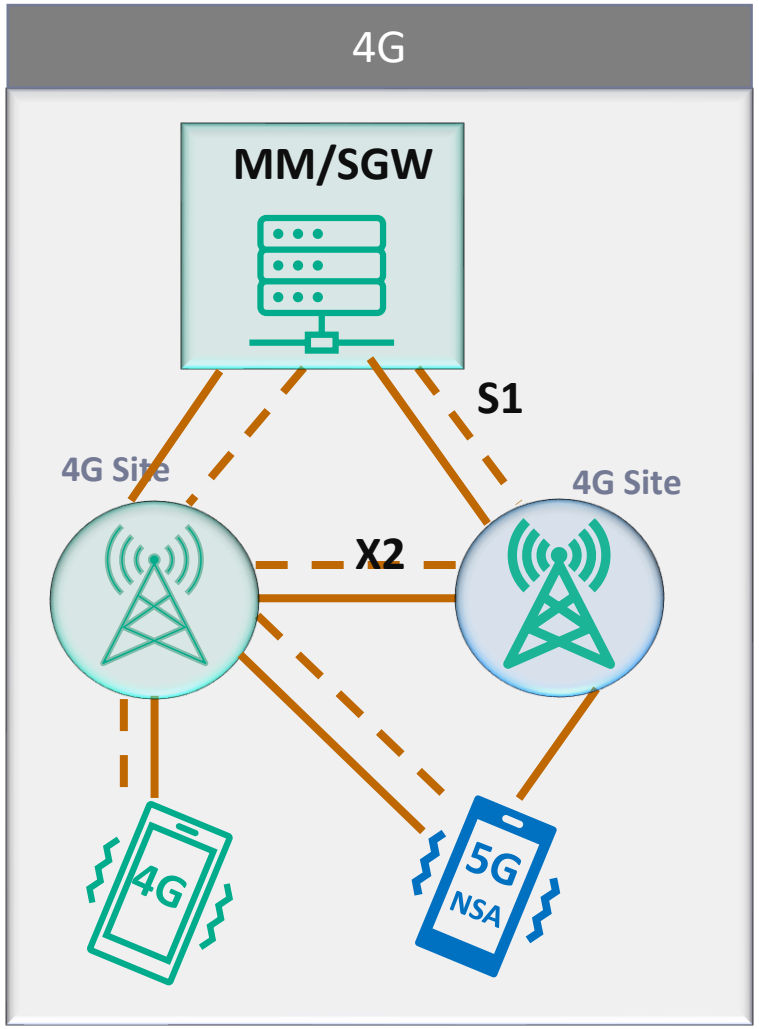

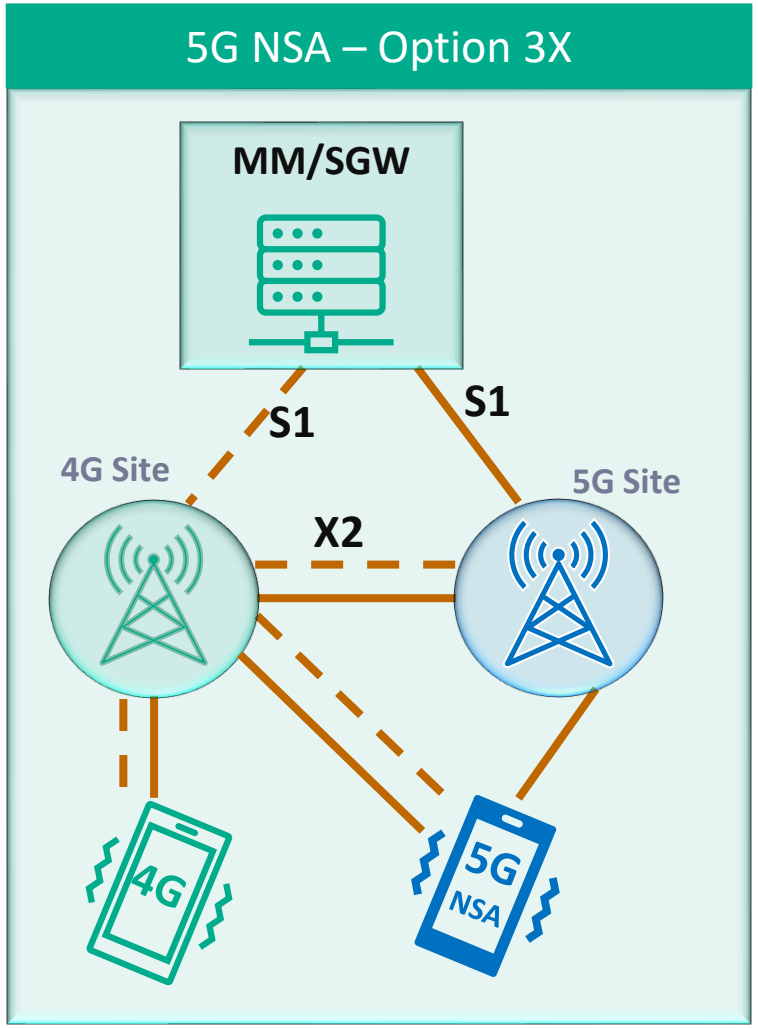

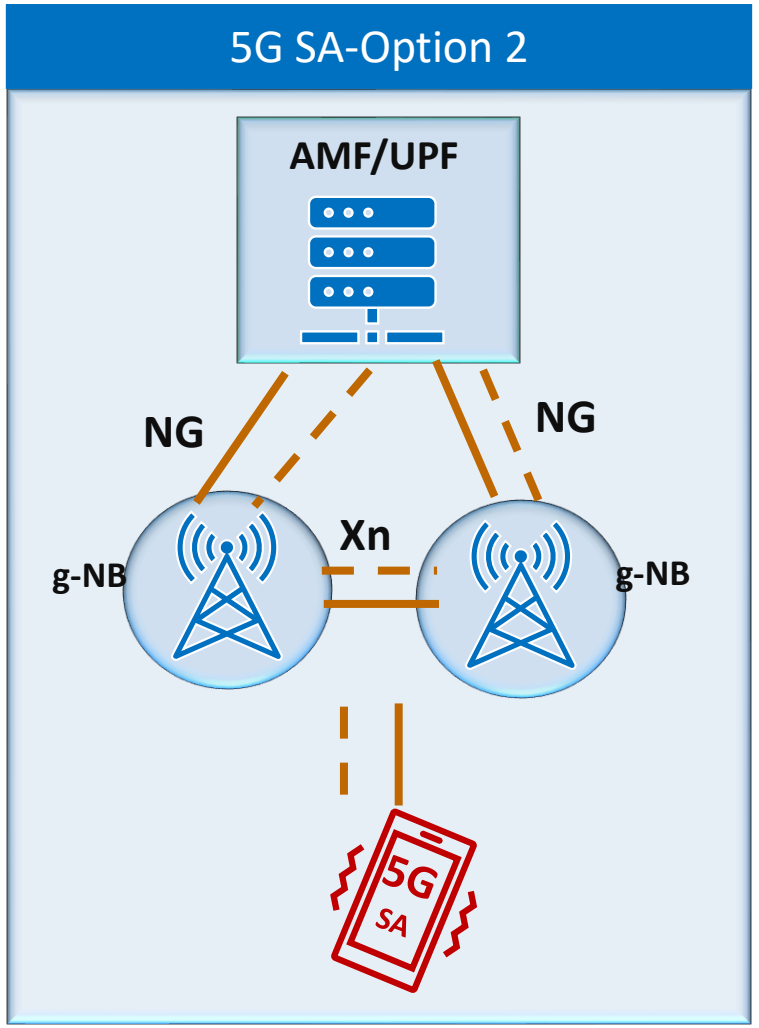

Control Plane — Signaling

User Plane — Data

Architecture: 4G ,5G NSA & 5G SA

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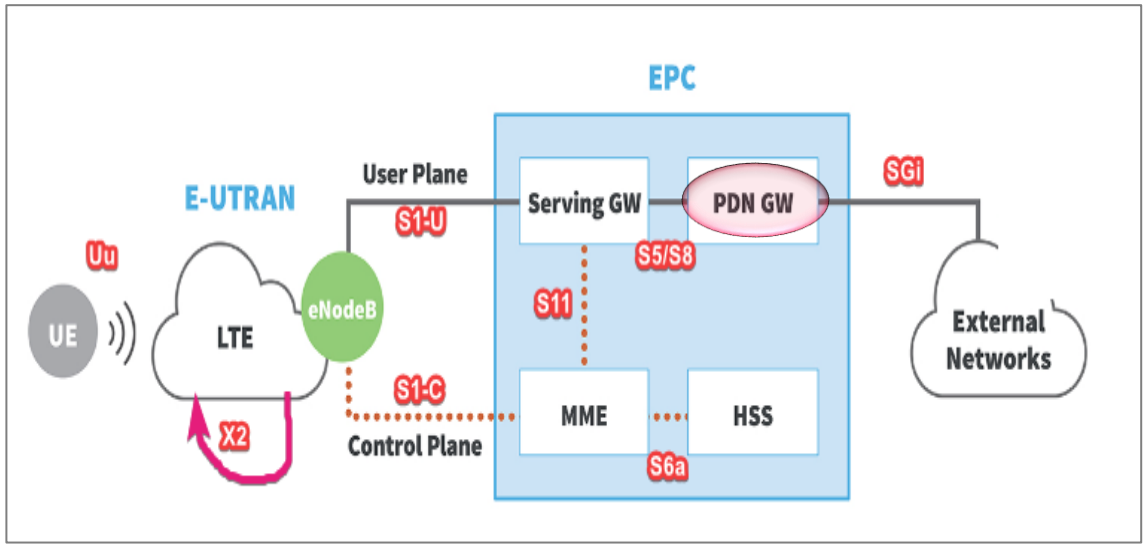

1. An important Characteristic of the 5G System is separating the user plane and control plane functions. This differs from the original 4G System architecture.
    1. 4G: P-GW provides both control plane and user plane functions(IP Address allocation & Packet Forwarding)
    2. 5G: SMF Provides IP Allocation, and UPF provides packet forwarding
2. User and Control plane separation allows independent scaling of the two functions
    1. Operators can add more user plane capabilities without having to add more control plane

    2. Minimize latency through distributing User plane and keeping it geographically close to the AN

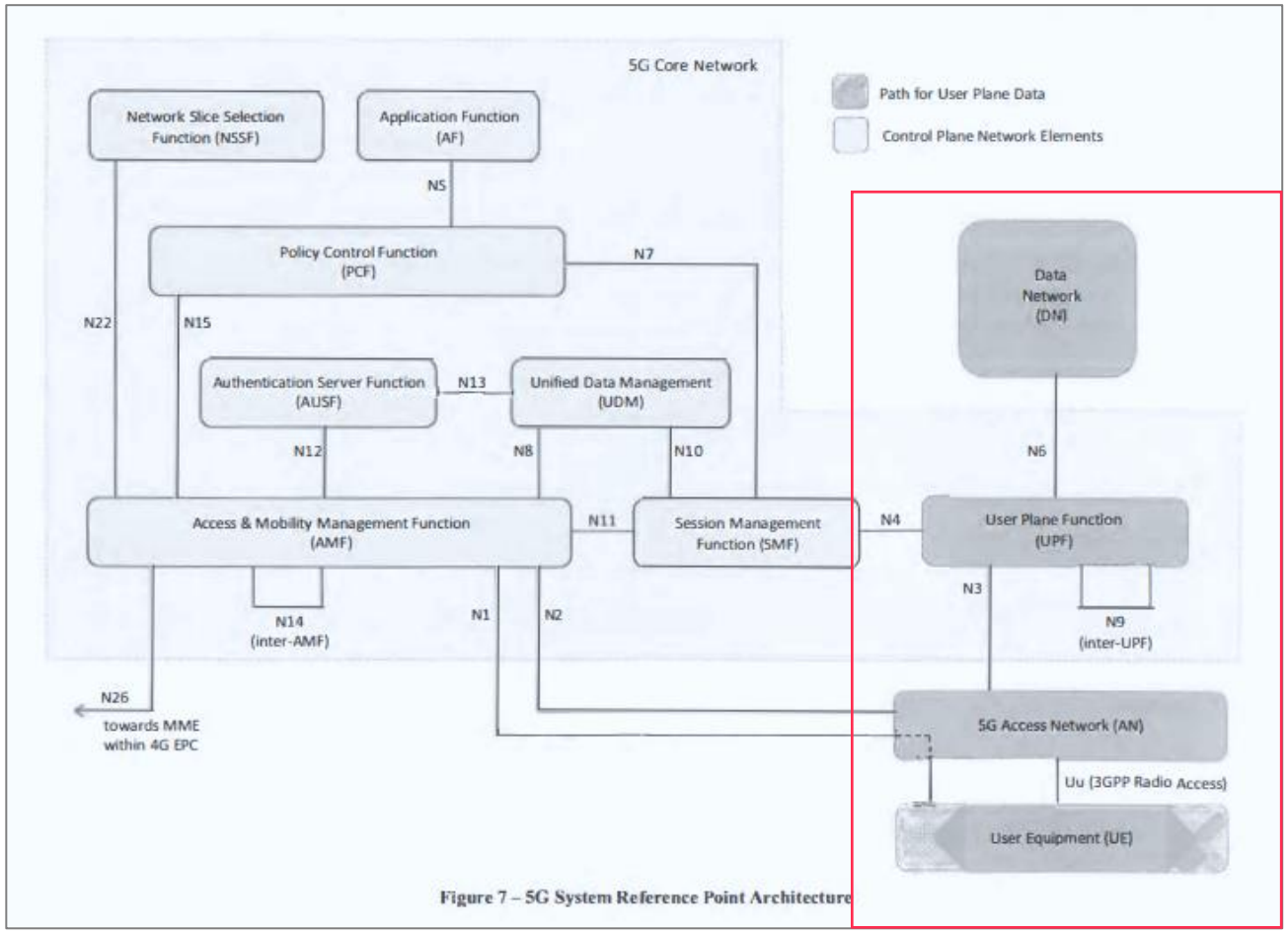

Figure 7 – 5G System Reference Point Architecture

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RAN Structure	QoS	Radio Protocol Stack
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Quality of Service: 4G & 5G

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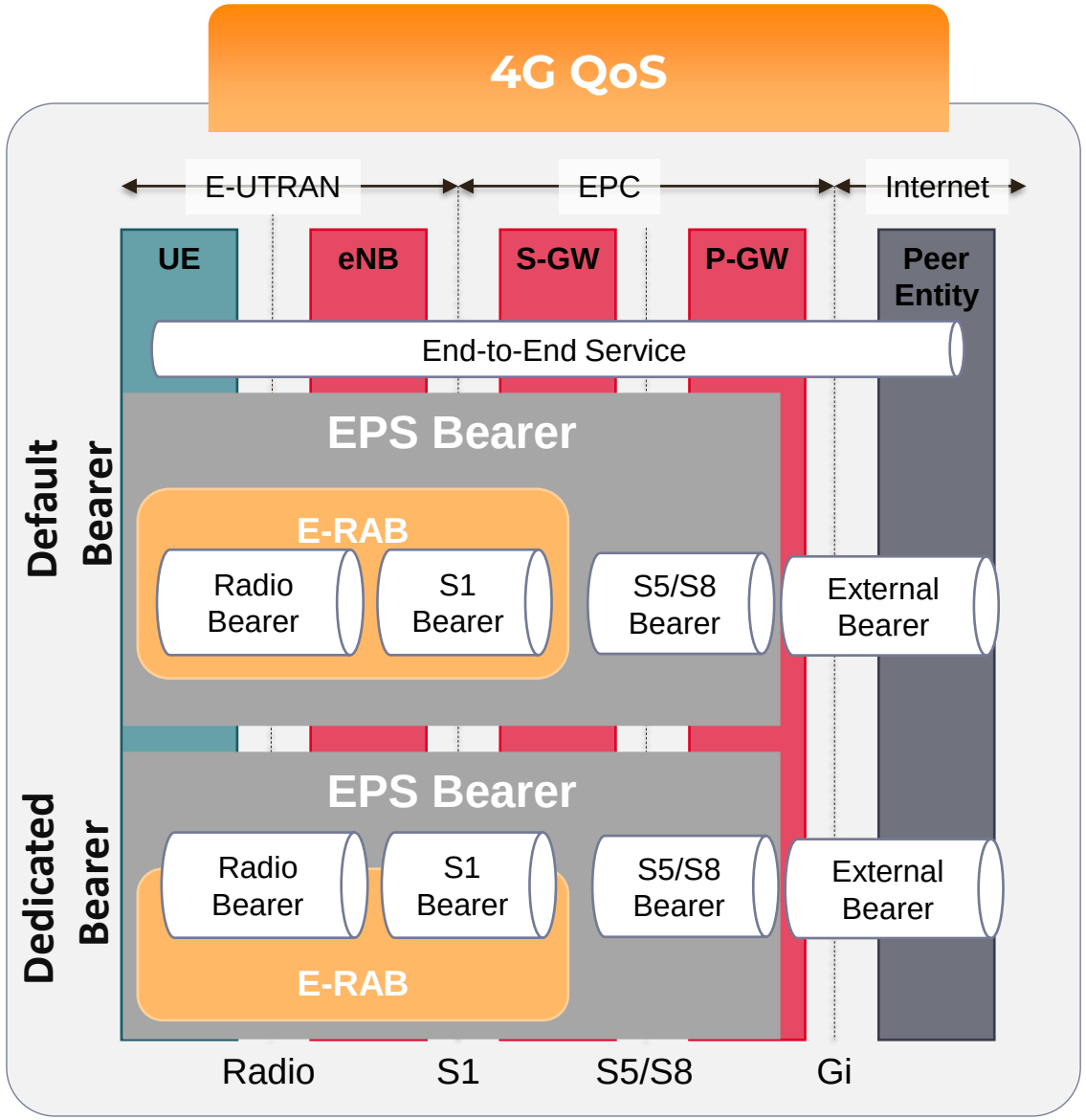

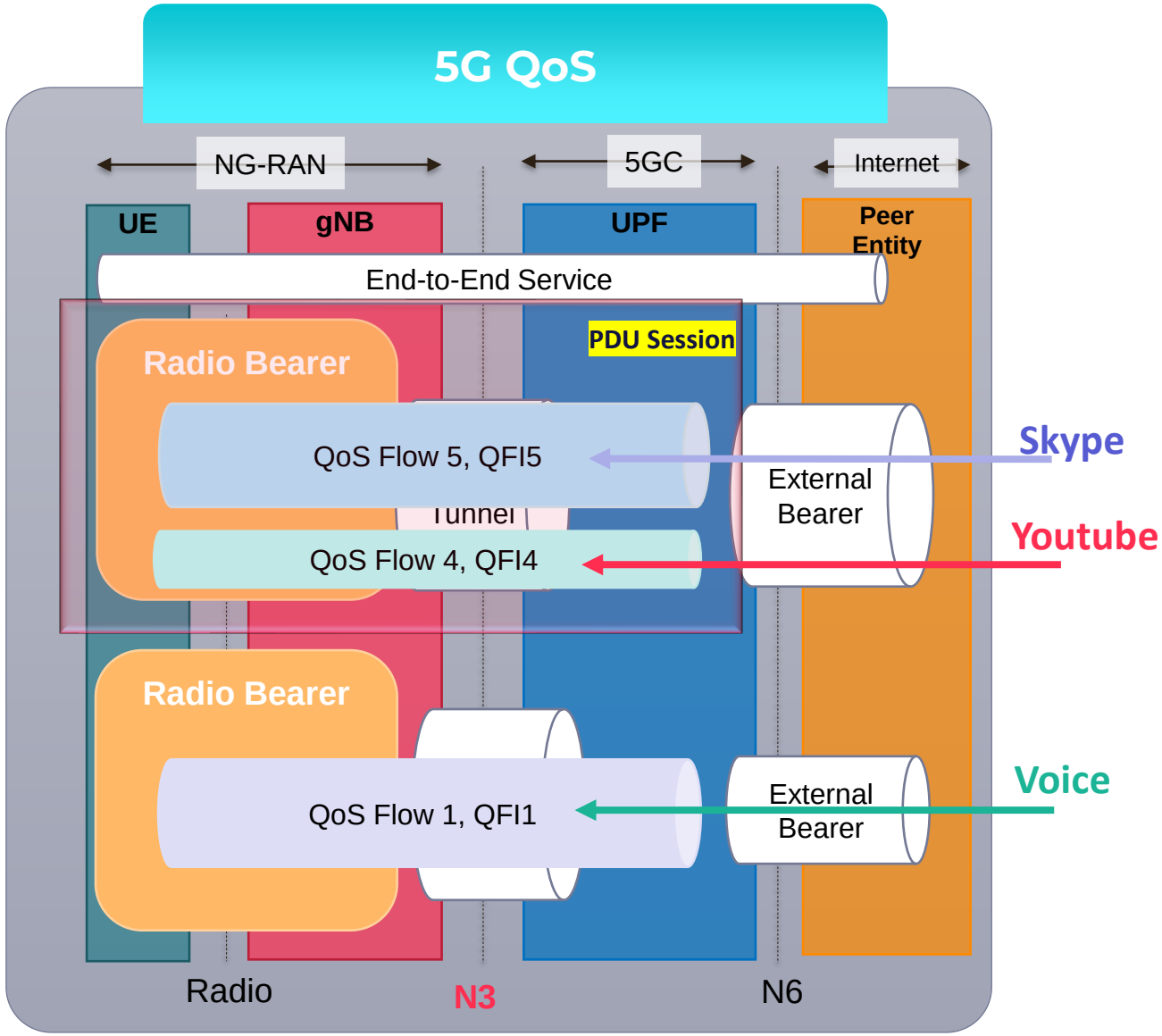

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RAN Structure	QoS	Radio Protocol Stack
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Radio Protocol Stack: SDAP Layer added in User-Plane

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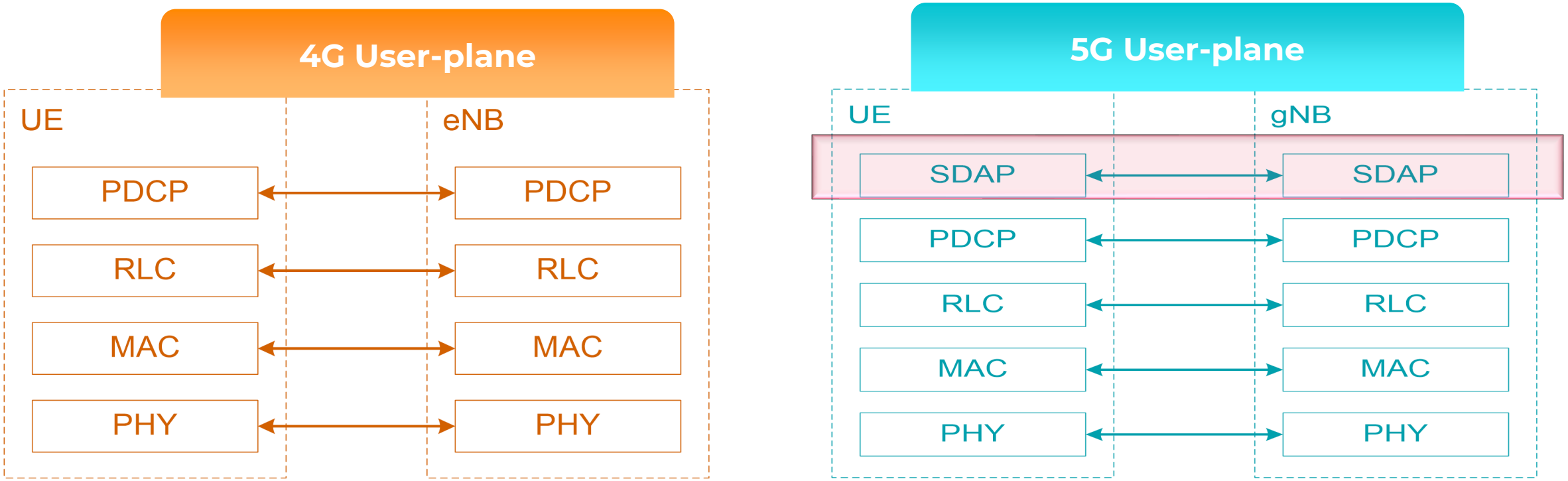

SDAP Primary Task:

- The new SDAP (Service Data Adaptation Protocol) primary function maps each QoS Flow onto a specific Data Radio Bearer
  - Multiple QoS Flows can be mapped onto a single DRB or,
  - Single QoS Flow can be mapped onto a single DRB.
- Note: QoS Flows belonging to different PDU Sessions are mapped onto different DRBs.

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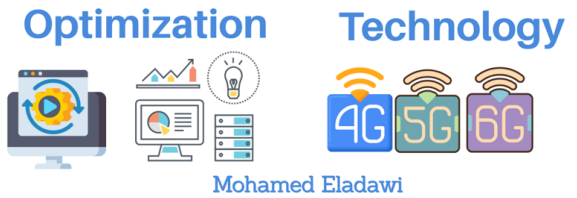
CONTENT

RAN Structure	QoS	Radio Protocol Stack
Frame Structure	Physical Channel & Signals	Link Budget

Overall Technology Comparison



	4G	5G
Bandwidth	Up to 20MHz	FR1 up to 100MHz, FR2 up to 400MHz, BWP
Numerology(SCS)	Fixed: 15kHz (1ms TTI)	Flexible: (15~120 kHz) (e.g 0.5msTTI @ 30kHz)
PBCH/SS	Wide Beam	Narrow Beam(Beam Sweeping Introduced)
Reference signal	CRS based	CSI-RS/DMRS based “CRS Free”
PDCCH Resource	Entire Bandwidth	RB level(CORESET)
PUCCH	Long Format	Long & Short Format
Waveform	UL: DFT-S-OFDM DL: OFDM	UL: DFT-S-OFDM or OFDM or (Dynamic) DL: OFDM
Modulation	UL: 64QAM as baseline UL 256 QAM Supported in higher versions	UL/DL: 256QAM as a baseline

5G Bandwidth

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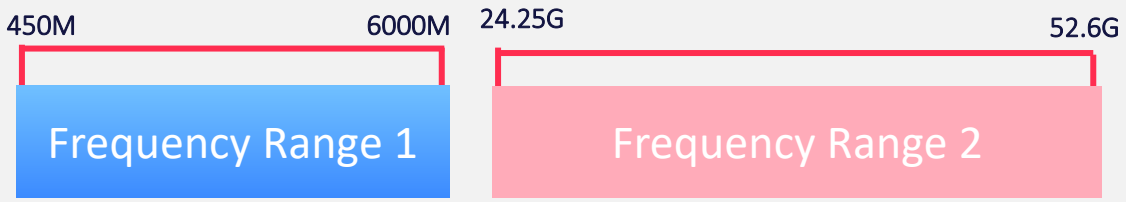
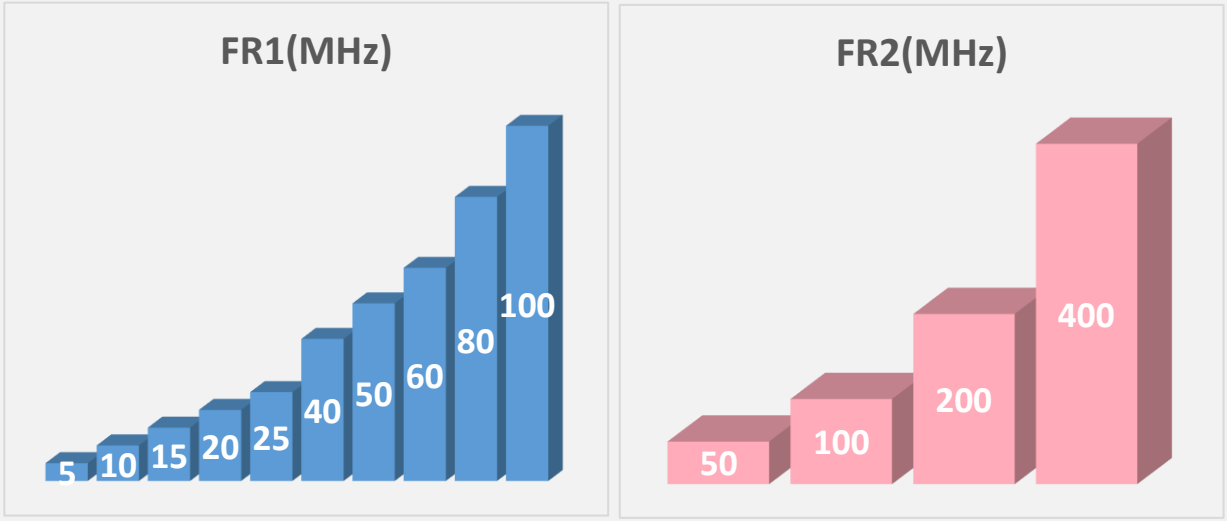
- Up to 20x Higher Bandwidth and New Spectrum Definition. (ex. mmwave)
- NR Offers Less Guard-band and Higher spectrum utilization

NR Frequency Ranges

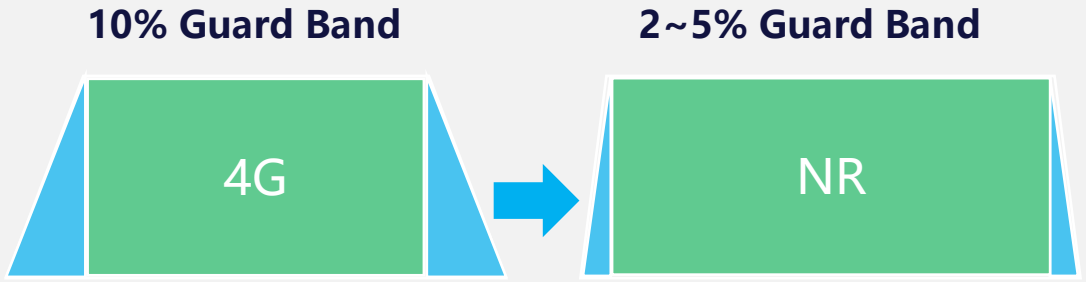


Available BW Per FR



*Source: 3GPP TS 38.101

Guard Band & Spectrum Utilization



NR Utilization by bandwidth and SCS

SCS [kHz]	20 MHz	25 MHz	40 MHz	50 MHz	60 MHz	80 MHz	100 MHz
	NRB and Spectrum Utilization (FR1: 400MHz ~6000MHz)						
15	106	133	216	270	-	-	-
	95.40%	95.80%	97.20%	97.20%	-	-	-
30	51	65	106	133	162	217	273
	91.80%	93.60%	95.40%	95.80%	97.20%	97.70%	98.30%
60	24	31	51	65	79	107	135
	86.40%	89.30%	91.80%	93.60%	94.80%	93.60%	97.20%

*Source: TS38.104

Frame Structure Comparison : 4G & 5G

NR is the same as 4G

Subframe 0	Subframe 1	Subframe 2	Subframe 3	Subframe 4	Subframe 5	Subframe 6	Subframe 7	Subframe 8	Subframe 9

1ms — One Radio Frame: 10ms — 1ms

Comparison

	4G	5G
Schedule Unit	LTE-Subframe 15 KHz	NR-Slot
Subframe Structure	LTE-2 Slot	NR-1~8 Slot

4G: Slot 0 | Slot 1

5G:

15 KHz	Slot 0							
30 KHz	Slot 0				Slot 1			
60 KHz	Slot 0		Slot 1		Slot 2		Slot 3	
120 KHz	Slot 0	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7

Frame and Subframe duration remained the Same for 5G
Number of Symbols in a slot is now fixed to 14 in 5G (4G is fixed to 7)
5G has a flexible numerology, which allows different configurations as the Slot Duration relies on SCS(Sduration = 1 /SCS)
5G is now using a Slot as a scheduling Unit instead of Sub-frame compared to 4G
NR RB Resource Grid is double 4G(14 vs. 7 OFDM symbols in one RB)

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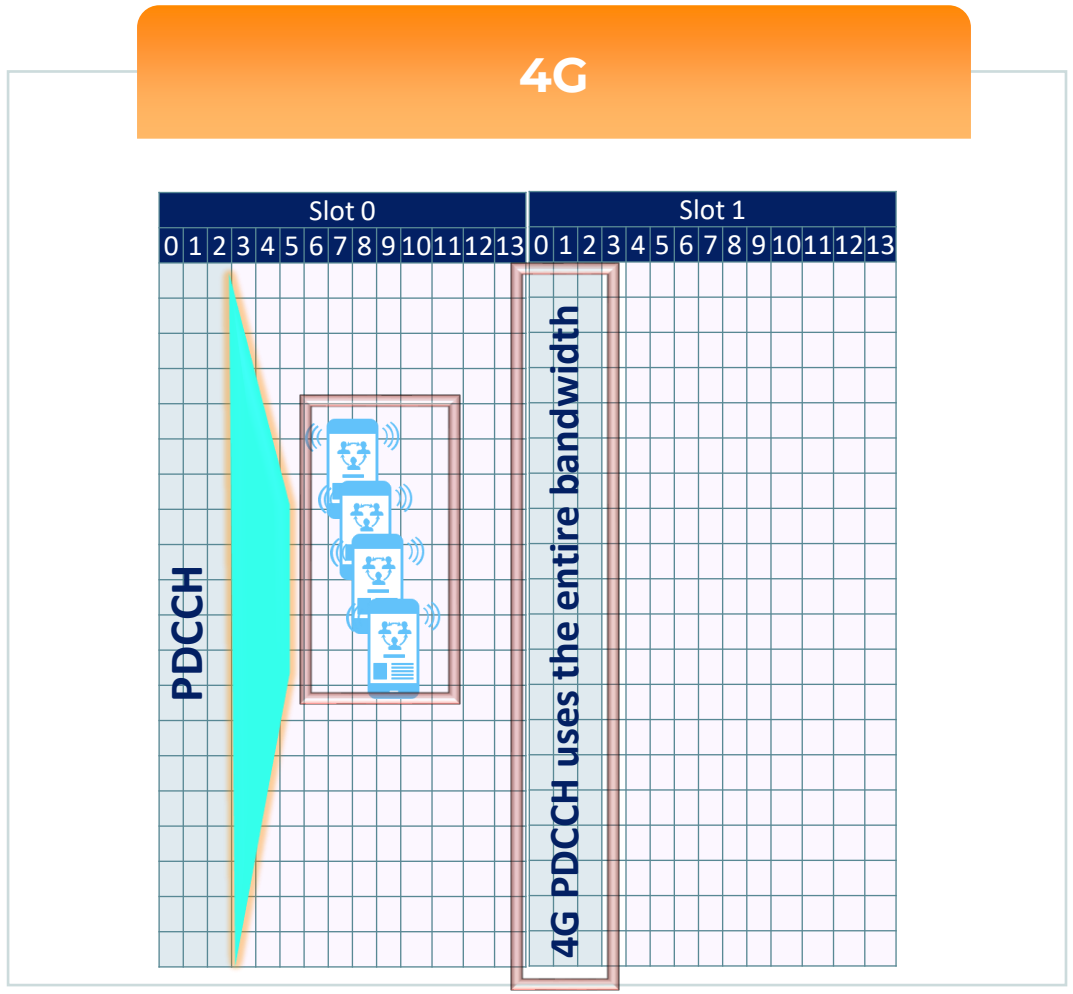
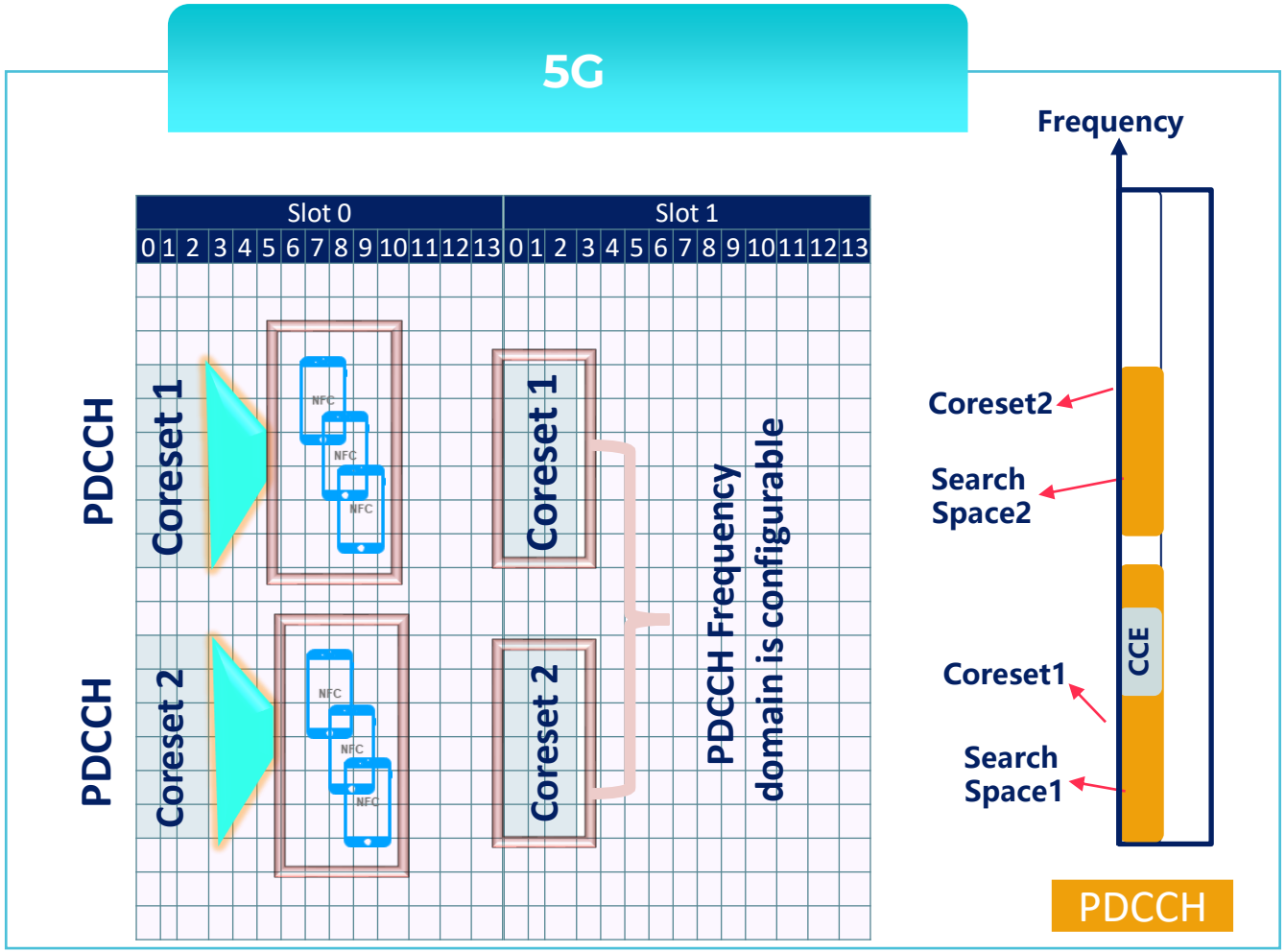
Physical Channel & Signals Comparison : 4G & 5G

	4G	5G	Remark
Physical Channels	PBCH	PBCH	Same function but PBCH combined within SSB in 5G
	PCFICH	**Removed**	PCFCH only indicates the symbol number of PDCCH, Indicated and included by MIB in NR
	PHICH	**Removed**	PHICH for ACK/NACK, Indicated in uplink DCI in NR
	PDCCH	PDCCH **(CORESET Introduced in NR)**	PDCCH introduced the CORESET concept to give more control over the Frequency domain
	PDSCH	PDSCH	Almost same with no change
	PRACH	PRACH	Almost same with no change
	PUCCH	PUCCH **(Introduced Long/Short PUCCH)**	5G PUCCH introduced a short format to support low-latency application
	PUSCH	PUSCH	Almost same with no change
Physical Signals	SS (PSS/SSS)	SS (PSS/SSS)	Same function but combined within SSB in 5G
	CRS(DMRS for PDSCH)	CSI-RS	Reference Signal used for channel demodulation; 5G is no longer using CRS
		DMRS for PBCH	
		DMRS for PDCCH	
		DMRS for PDSCH	
	-	PT-RS	Phase Noise Tracking (New in NR)

Downlink Comparison: Physical Downlink Control Channel(PDCCH)

- In LTE, PDCCH control channels are always distributed across the entire system bandwidth.
- NR PDCCHs are designed to transmit in a configurable control resource set (Called CORESET).

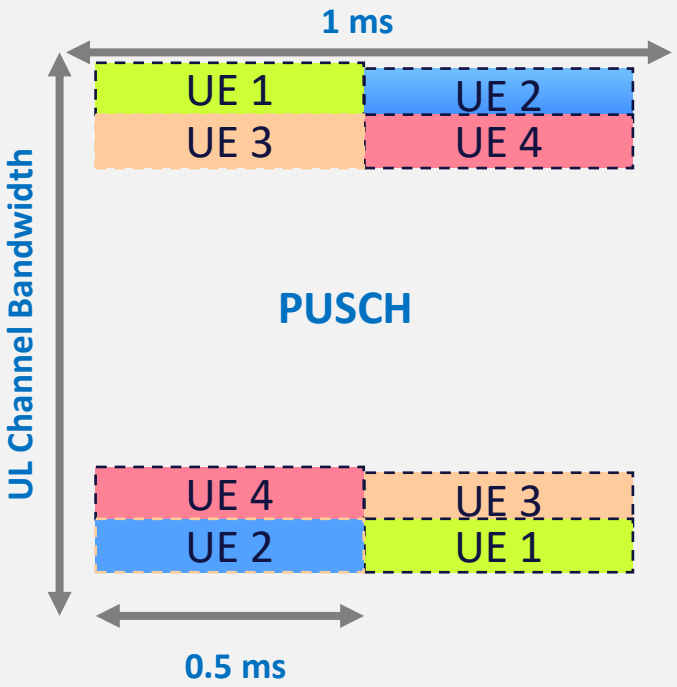




The time domain is configurable in both 4G & 5G: first 1~3 OFDM symbols of each slot.

Uplink Comparison: Physical Uplink Control Channel(PUCCH)

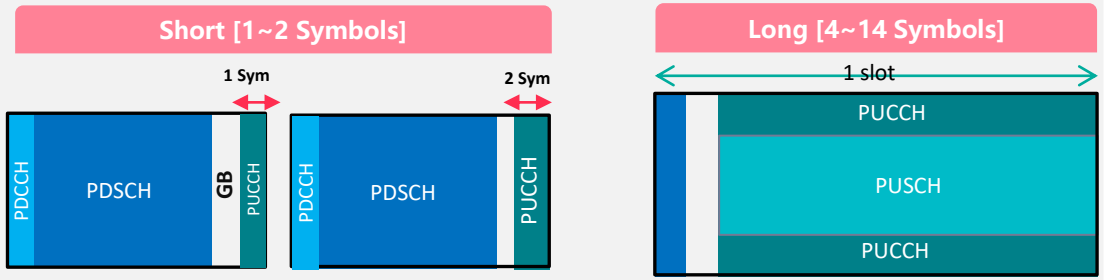
4G



5G

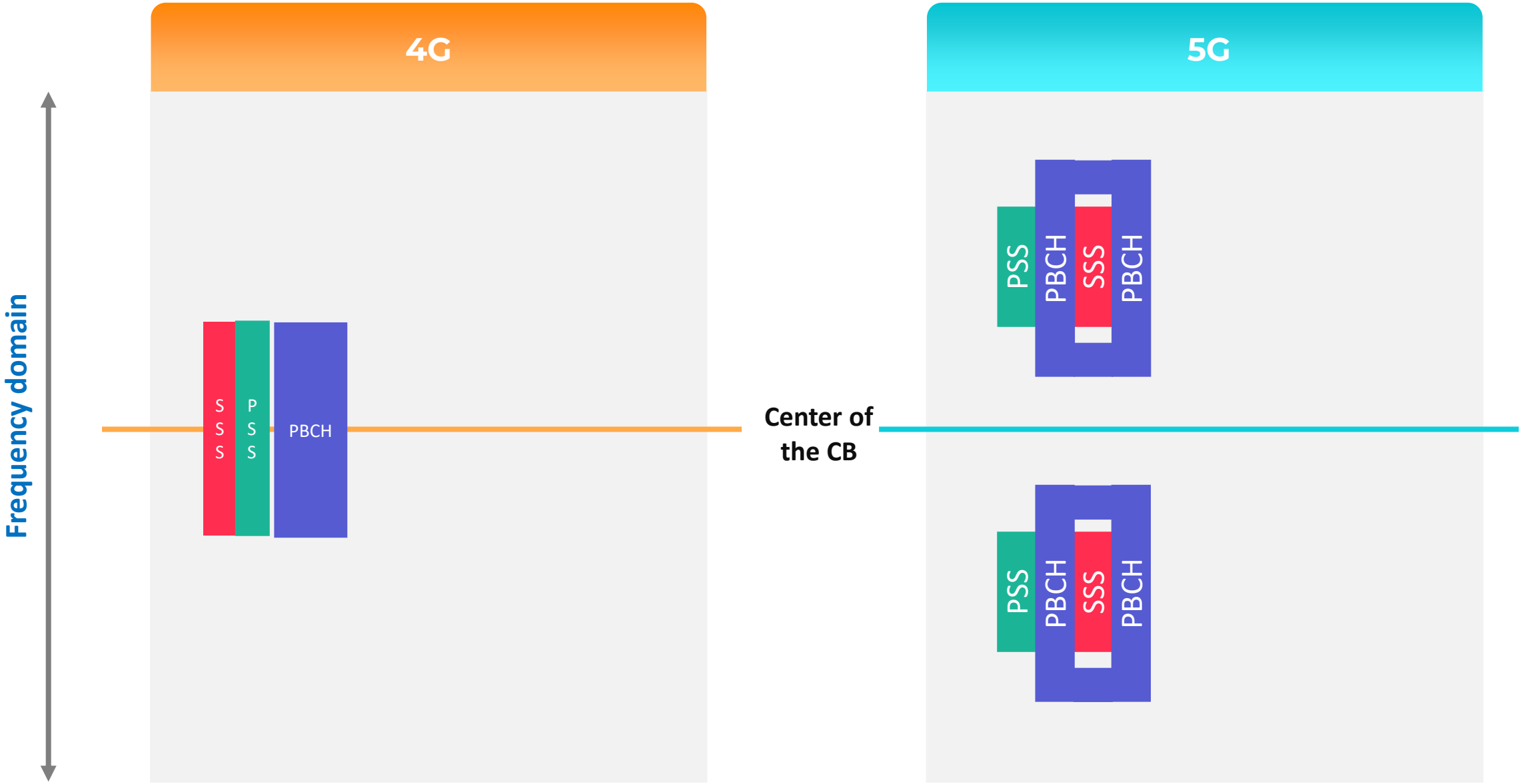
1~2 Symbols over the complete BW
Better Latency

4~14 Symbol and sent in the UL Slot



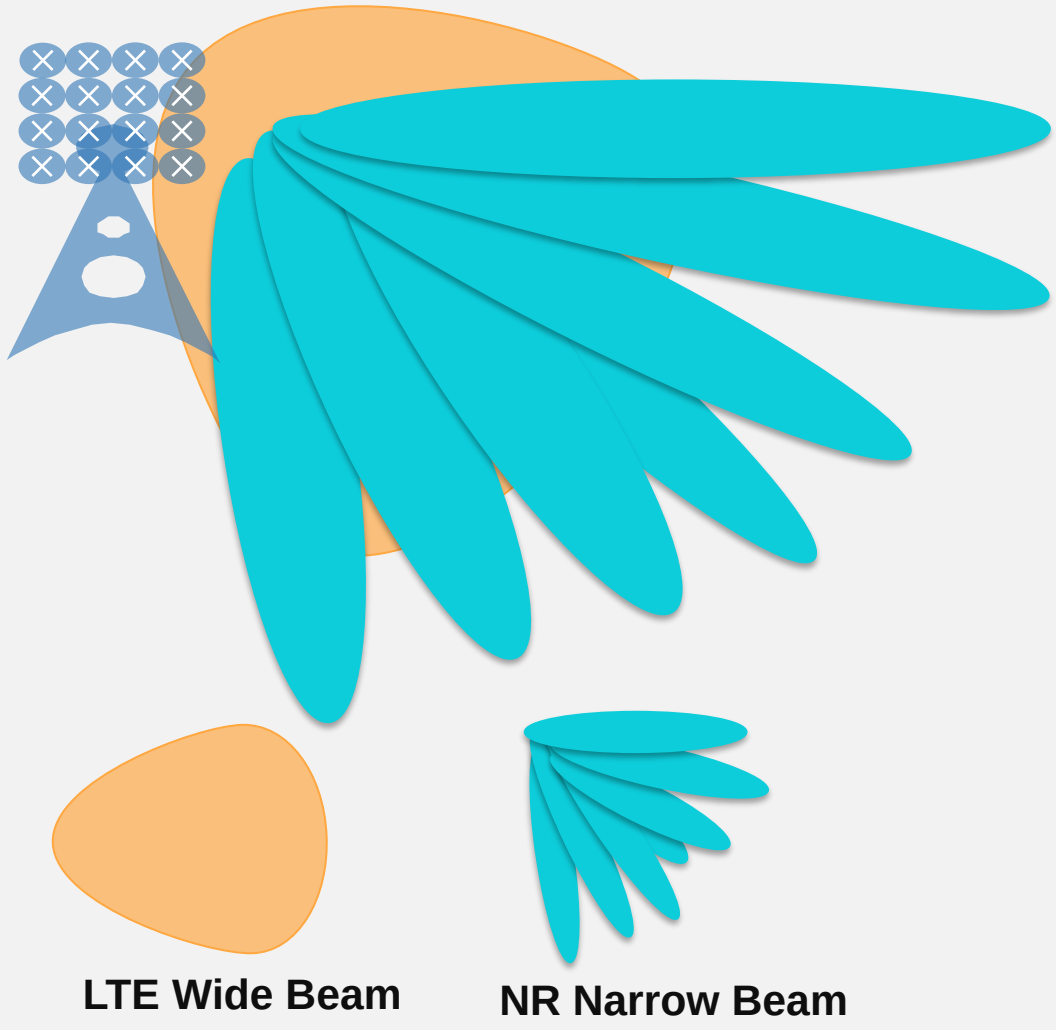
PUCCH format	OFDM symbols	#Bits	Description
0	1 – 2	≤2	Short PUCCH for small UCI payloads
1	4 – 14	≤2	Long PUCCH for small UCI payloads
2	1 – 2	>2	Short PUCCH for large UCI payloads
3	4 – 14	>2	Long PUCCH for large UCI payloads
4	4 – 14	>2	Long PUCCH for moderate UCI payloads

PBCH & Synchronization Signals: 4G & 5G

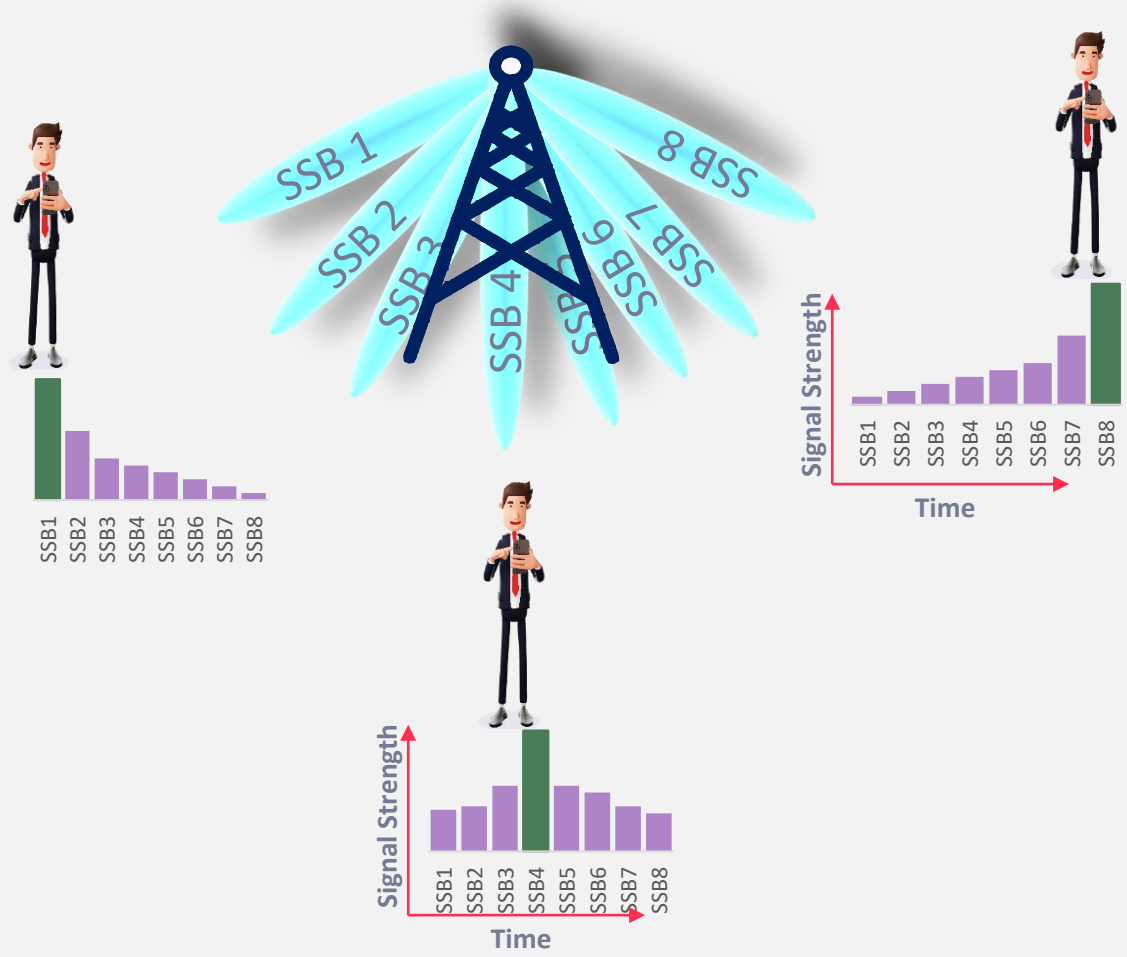


Broadcast Channel Comparison: 4G & 5G

Broadcast channel



SSB Beam Sweeping



Reference Signal Overhead comparison: 4G & 5G

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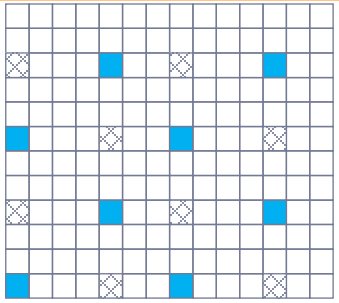
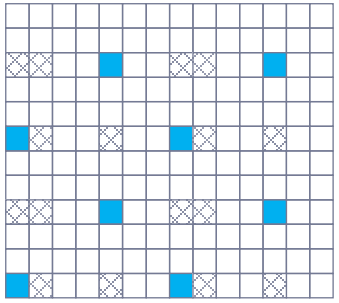
4G



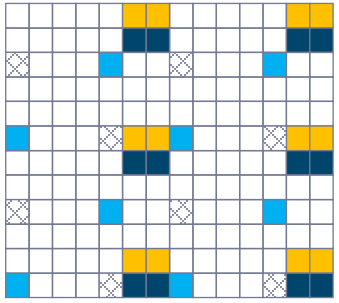
2T2R

$$RS_{Overhead} = \frac{16}{12 \times 14} = 9\sim10\ \%$$



4T4R

$$RS_{Overhead} = \frac{16 + 8}{12 \times 14} = 14\%$$



TM9

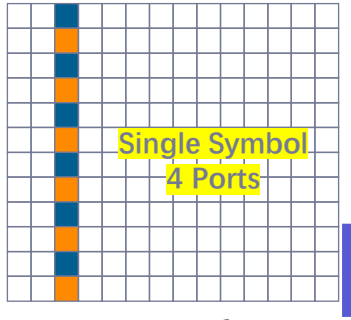
$$RS_{Overhead} = \frac{16 + 12}{12 \times 14} = 16\sim17\%$$

5G

Type1

1000/1001/1004/1005

1002/1003/1006/1007



7.2% for Rank 4 and MUMIMO

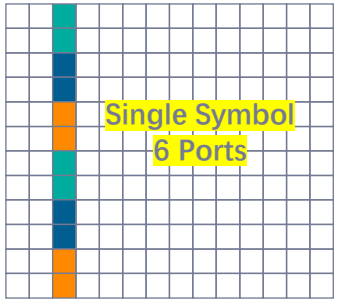
$$RS\ Ratio = \frac{6}{12 \times 14} = 3.6\%$$

Type2

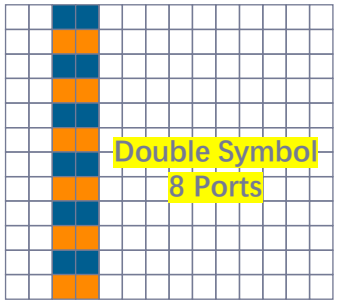
1000/1001/1006/1007

1002/1003/1008/1009

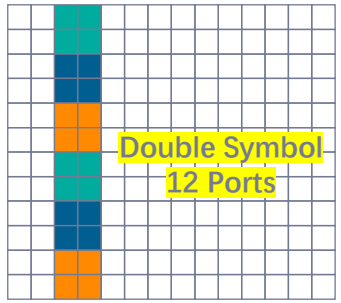
1004/1005/1010/1011



$$RS\ Ratio = \frac{4}{12 \times 14} = 2.4\%$$



$$RS\ Ratio = \frac{12}{12 \times 14} = 7\%$$



$$RS\ Ratio = \frac{8}{12 \times 14} = 4.8\%$$

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Key differences in Link Budgets: 4G & 5G

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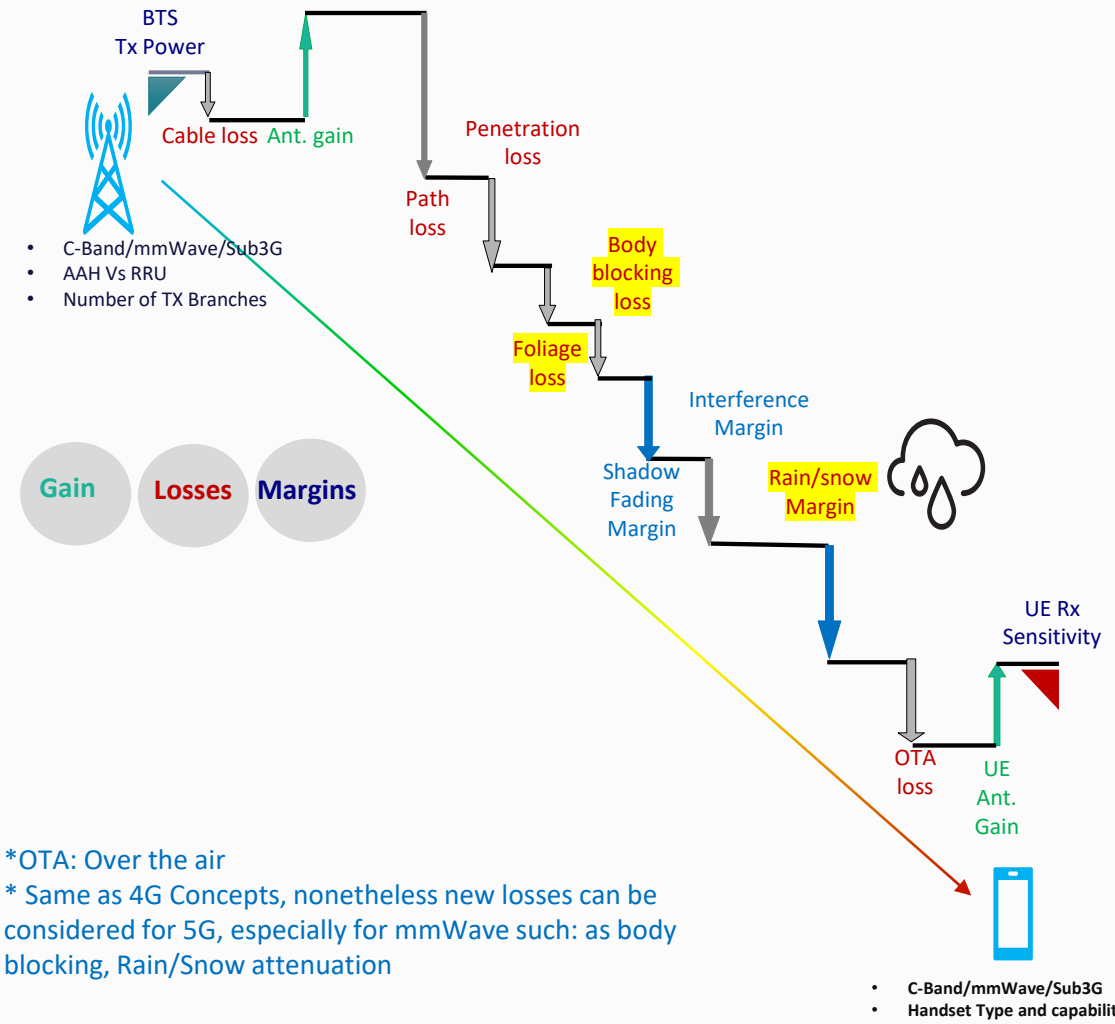
4G & 5G almost have the same Link Budget Basic Methodology



*OTA: Over the air

* Same as 4G Concepts, nonetheless new losses can be considered for 5G, especially for mmWave such: as body blocking, Rain/Snow attenuation

Main Consideration

Factor	4G	5G
Cable loss	Cable Loss considered for RRU/RRH	No Cable Loss in AAU/AAS
BTS Antenna gain	18dBi (Typical Antenna)	25dBi (Active Antenna: 64T64R)
Propagation model	Okumura-Hata/Cost231-Hata	Uma, Rma, and Umi
Penetration loss	Relatively Small	High Penetration Loss for Higher Frequencies
Interference margin	Relatively Large	Less interference due to Narrow Beams

- Link Budget is counting all of the gains and losses from the TX through the medium(Free Space, Cables, etc.) to the receiver
- Simple Link Budget Equation:
  - Received Power(dBm) = TX Power(dBm) + Gains - Losses