System Architecture 2018 Fall 5G (1)

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Information Engineering

1G to 4G and 5G

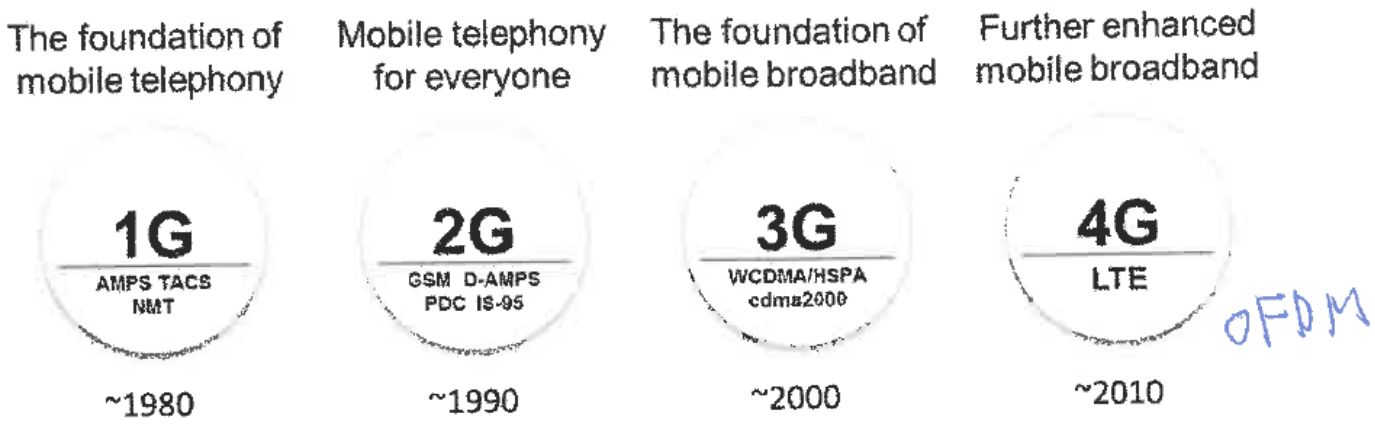
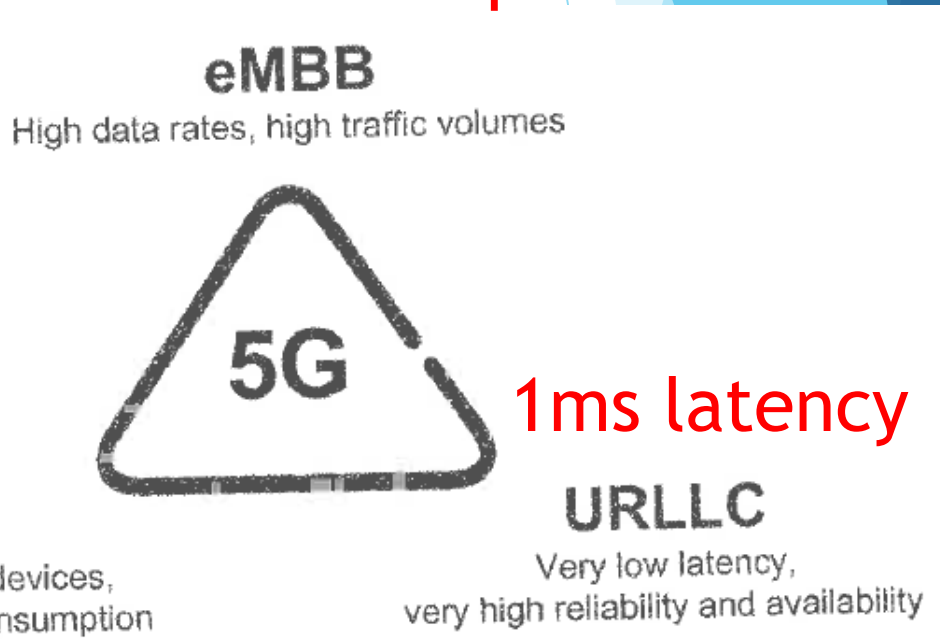


FIGURE 1.1

The different generations of mobile communication.

Peak 20Gbps



10^6 devices/1km^2

1ms latency

FIGURE 1.2

High-level 5G use-case classification.

5G = eLTE + New Radio

NR reuses many of the structures and features of LTE. However, being a new radio-access technology means that NR, unlike the LTE evolution, is not

NRはLTEの構造を再利用

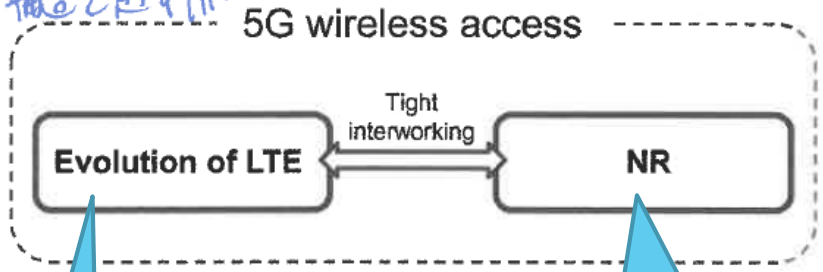
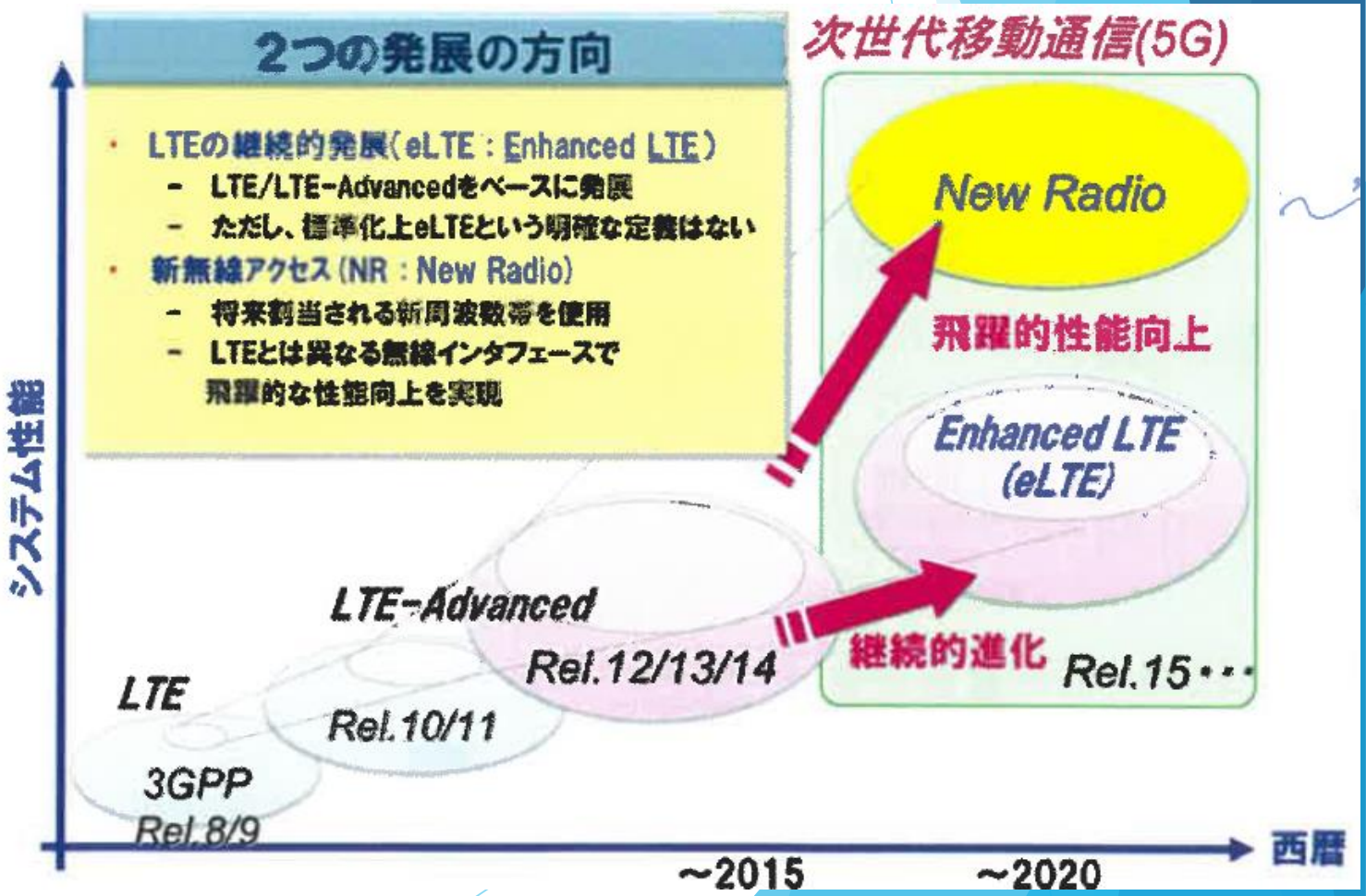


FIGURE 1.3

Evolution of LTE and NR jointly providing the overall 5G radio-access evolution.

Ultra High Speed But Small Area

Mobility Connectivity Wide Area



2020 Requirements

Table 2.1 Overview of Minimum Technical Performance Requirements for IMT-2020

Parameter	Minimum Technical Performance Requirement
Peak data rate	Downlink: 20 Gbit/s Uplink: 10 Gbit/s
Peak spectral efficiency	Downlink: 30 bit/s/Hz Uplink: 10 bit/s/Hz
User-experienced data rate	Downlink: 100 Mbit/s Uplink: 50 Mbit/s
Fifth percentile user spectral efficiency	3 × IMT-Advanced
Average spectral efficiency	3 × IMT-Advanced
Area traffic capacity	10 Mbit/s/m^2 (indoor hotspot for eMBB)
User plane latency	4 ms for eMBB 1 ms for URLLC
Control plane latency	20 ms
Connection density	1,000,000 devices per km^2
Energy efficiency	Related to two aspects for eMBB: a. Efficient data transmission in a loaded case b. Low energy consumption when there is no data The technology shall have the capability to support a high sleep ratio and long sleep duration
Reliability	$1-10^{-5}$ success probability of transmitting a layer 2 PDU (Protocol Data Unit) of 32 bytes within 1 ms, at coverage edge in Urban Macro for URLLC
Mobility	Normalized traffic channel data rates defined for 10, 30, and 120 km/h at ~1.5 × IMT-Advanced numbers Requirement for high-speed vehicular defined for 500 km/h (compared to 350 km/h for IMT-Advanced)
Mobility interruption time	0 ms
Bandwidth	At least 100 MHz and up to 1 GHz in higher-frequency bands. Scalable bandwidth shall be supported

Frequency Bands of New Radio (NR) in Range1 (Low Frequency)

Table 3.1 Operating Bands Defined by 3GPP for NR in Frequency Range 1

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 (Americas)
n5	824–849	869–894	FDD	Americas, Asia
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	4400–5500	4400–5500	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	

(Continued)

in Range2 (High Frequency)

Table 3.2 Operating Bands Defined by 3GPP for NR in Frequency Range 2

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)

NR Overview

Compared to LTE, NR provides many benefits. Some of the main ones are:

- exploitation of much higher-frequency bands as a mean to obtain additional spectra to support very wide transmission bandwidths and the associated high data rates;
- ultra-lean design to enhance network energy performance and reduce interference;
- forward compatibility to prepare for future, yet unknown, use cases and technologies;
- low latency to improve performance and enable new use cases; and
- a beam-centric design enabling extensive usage of beamforming and a massive number of antenna elements not only for data transmission (which to some extent is possible in LTE) but also for control-plane procedures such as initial access.

High Frequency

Ultra Low Power

For Future

Low Latency for New Service

Beamforming and Massive Antenna

Spectrum and Subcarrier Spacing

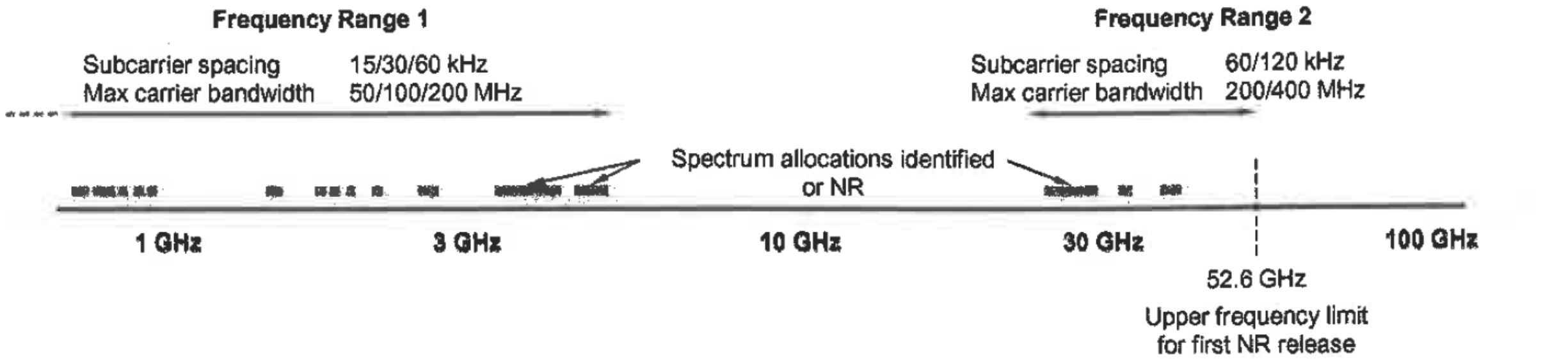


FIGURE 5.2

Spectra identified for NR and corresponding subcarrier spacings.

Short OFDM SYMBOL LENGTH

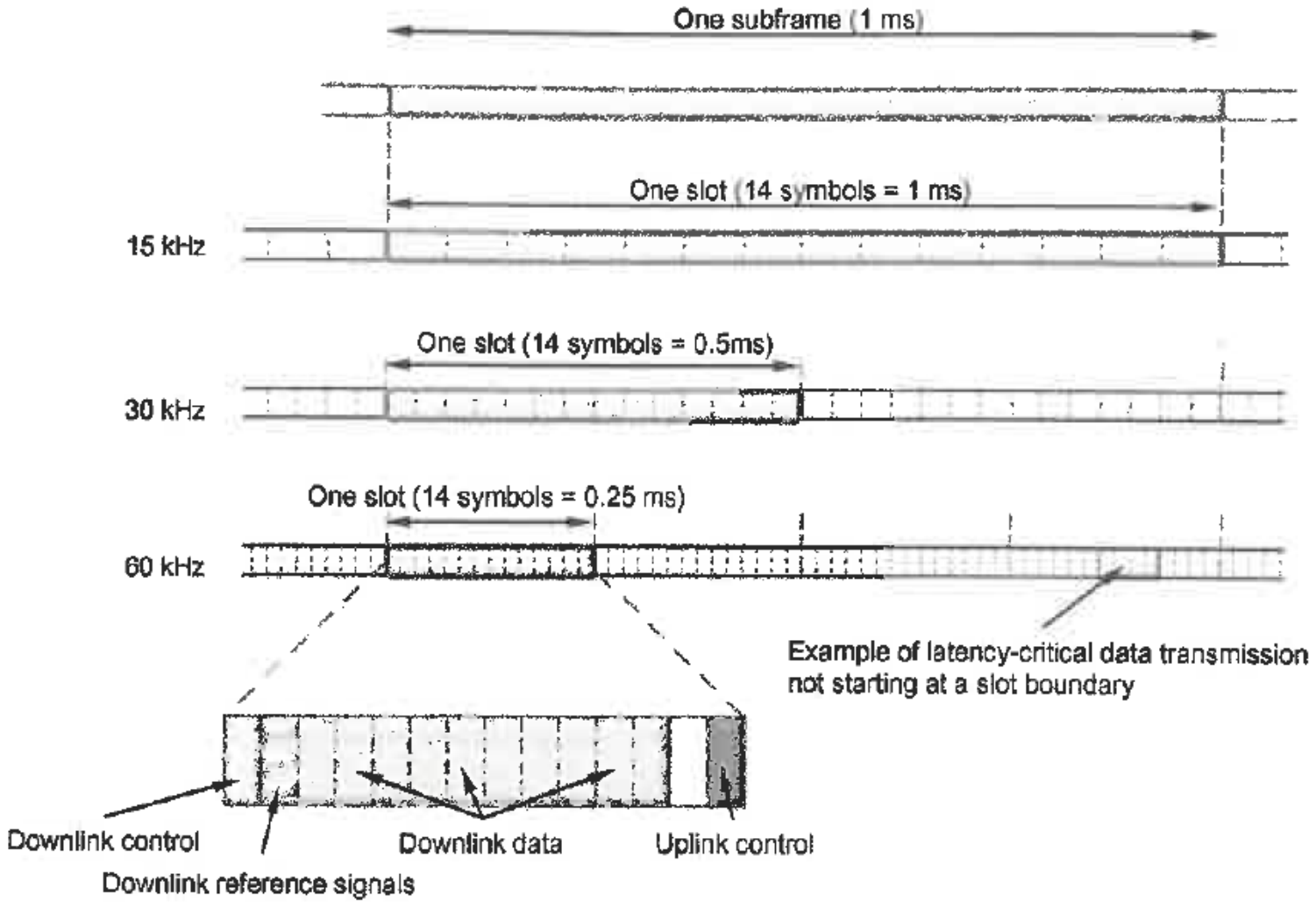
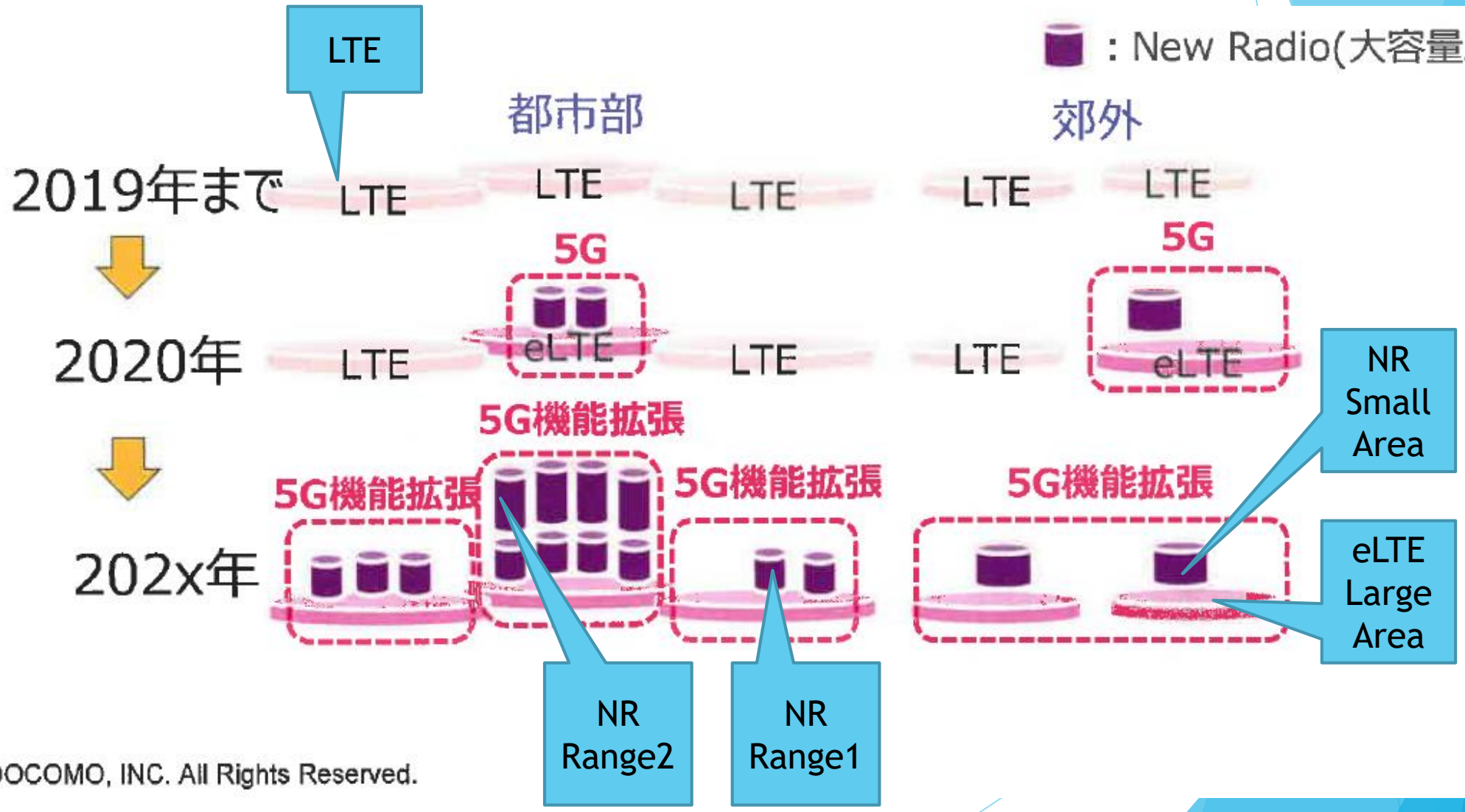


FIGURE 5.3

Frame structure (TDD assumed in this example).

NTT Docomo's Area PLAN



Many Antenna for Beamforming

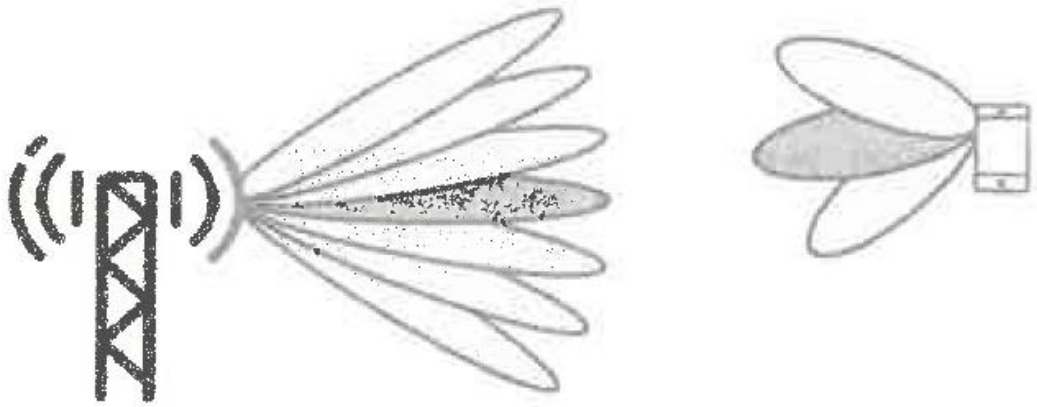
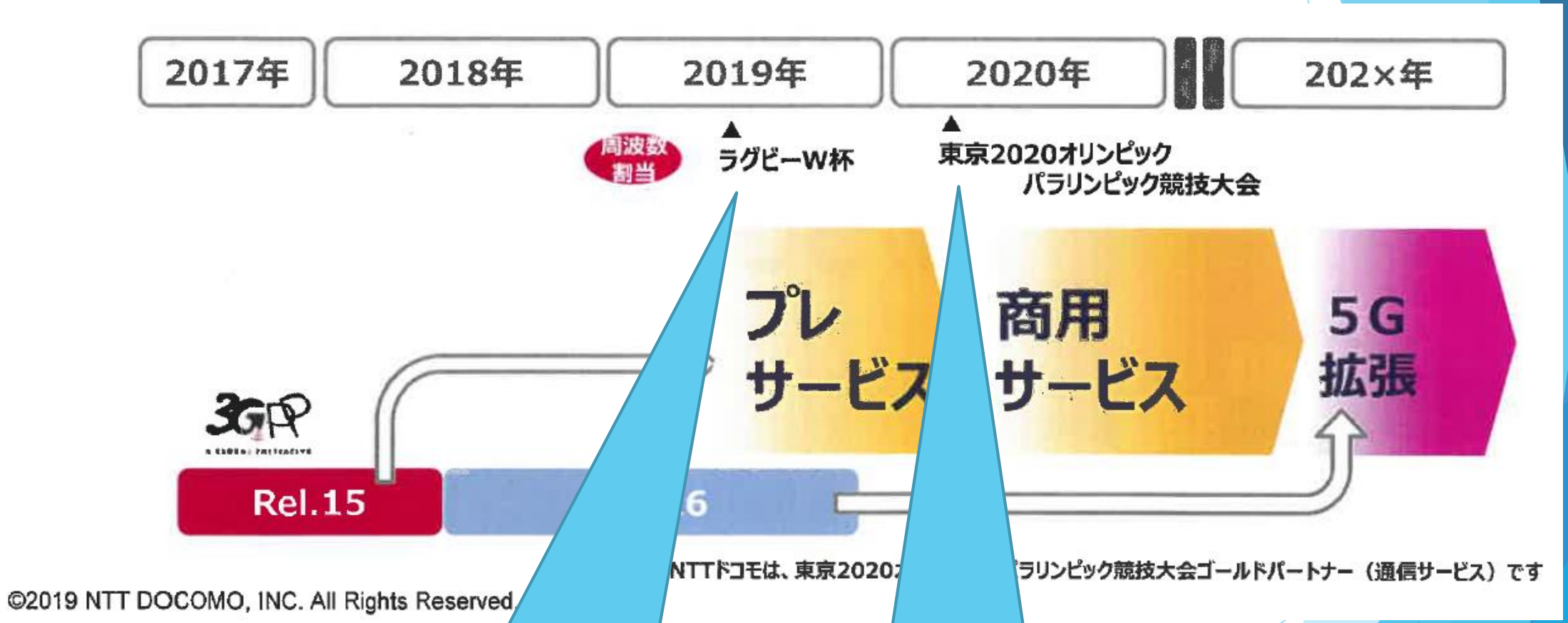


FIGURE 5.5

Beamforming in NR.

Twelve orthogonal demodulation reference signals are specified for multi-user MIMO transmission purposes, while an NR device can maximally receive eight MIMO layers in the downlink and up to four layers in the uplink. Moreover, additional configuration of a phase tracking reference signal is introduced in NR since the increased phase noise power at high carrier frequency bands otherwise will degrade demodulation performance for larger modulation constellations, for example 64 QAM.

NTT Docomo's Time Schedule



2019/September (Rugby World Cup)
100 Pre-Service Area in Japan
10 Pre-Service Area in Okinawa
300m Small Area Service

2020/July
Public 5G Service
(2020 Olympic)