FWA 26 GHz

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5G NR – Radio frequencies

The air interface defined by 3GPP for 5G is known as **New Radio (NR)**

2 frequency bands, FR1 (below 6 GHz) and FR2 (mmWave), each with different capabilities.

Frequency Range 1 (< 6 GHz)

- The maximum channel bandwidth defined for FR1 is 100 MHz, due to the scarcity of continuous spectrum in this crowded frequency range. The band most widely being used for 5G in this range is 3.3 – 4.2 GHz and 2G, 3G, 4G frequency bands

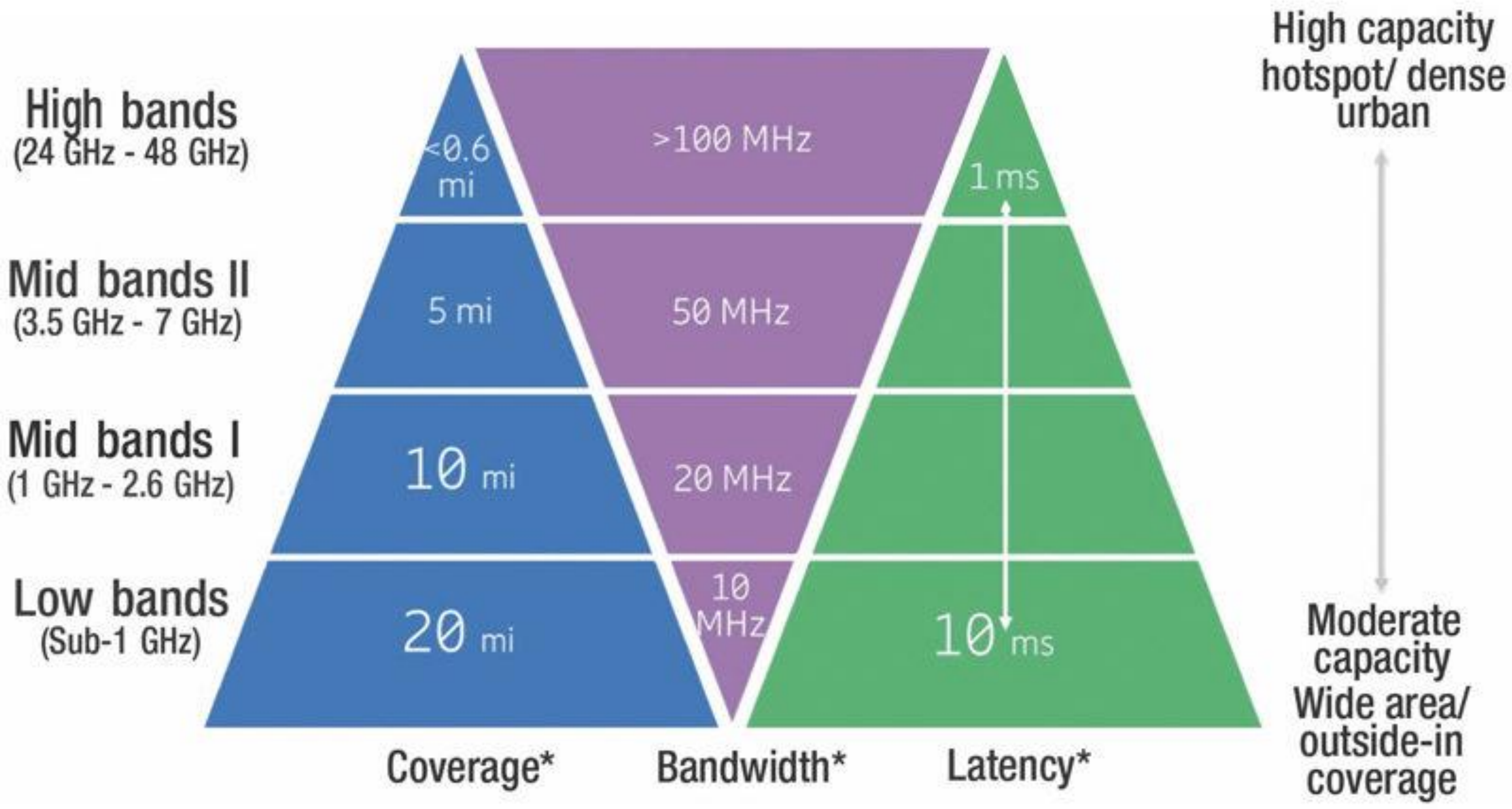
Frequency Range 2 (> 24 GHz) mmWave

- The minimum channel bandwidth defined for FR2 is 50 MHz and the maximum is 400 MHz, with two-channel aggregation supported in 3GPP Release 15. The higher the frequency, the greater the ability to support high data-transfer speeds.

5G NR physical layer

Parameter	FR1	FR2
Carrier Aggregation	16 contiguous and non-contiguous CCs with different numerologies (8 in FR1 and 8 in FR2)	
Bandwidth per carrier	5, 10, 15, 20, 25, 30, 40, 50, 60, 70 80, 90, 100 MHz	50, 100, 200, 400, 800, 2000 MHz
Subcarrier spacing	15, 30, 60 kHz	60, 120, 240 kHz
Duplex mode	FDD, TDD	TDD
Max. number of subcarriers	3300 (FFT4096 mandatory)	
Modulation scheme	QPSK, 16-QAM, 64-QAM, 256-QAM, in Rel 17: 1024-QAM (only DL), $\pi/2$-BPSK (only UL)	
Radio frame length	10 ms	

Coverage, Bandwidth, Latency



5G NR, Frequency Range 2

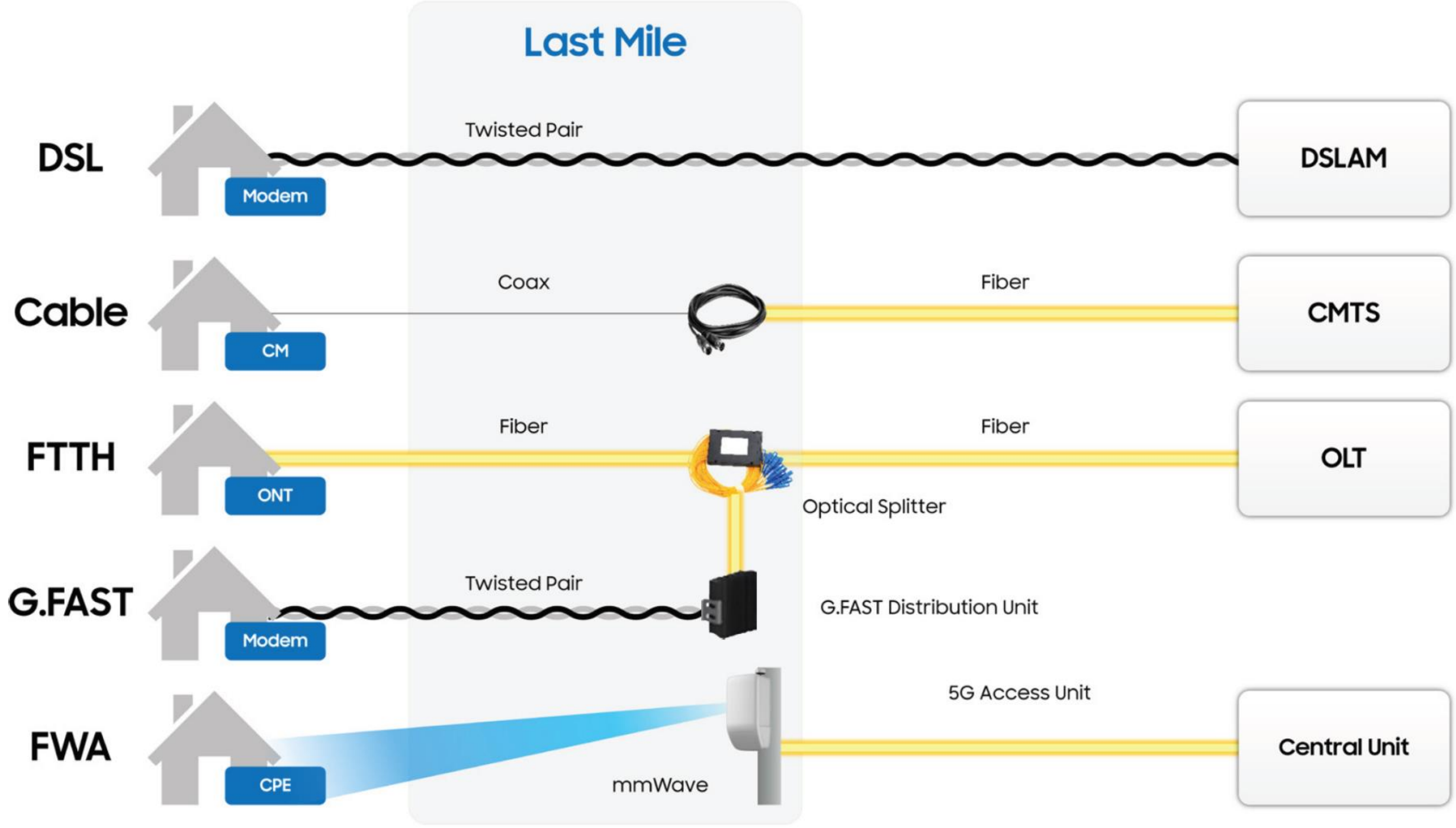
FR2	Band [GHz]	Name	Uplink / Downlink [GHz]			Channel bandwidths [MHz]	Duplex Mode
n257	**28**	**LMDS**	26,50	–	29,50	50, 100, 200, 400	TDD
n258	**26**	**K-band**	24,25	–	27,50	50, 100, 200, 400	TDD
n259	**41**	**V-band**	39,50	–	43,50	50, 100, 200, 400	TDD
n260	**39**	**Ka-band**	37,00	–	40,00	50, 100, 200, 400	TDD
n261	**28**	**Ka-band**	27,50	–	28,35	50, 100, 200, 400	TDD
n262	**47**	**V-band**	47,20	–	48,20	50, 100, 200, 400	TDD
n263	**60**	**V-band**	57,00	–	71,00	100, 400, 800, 1600, 2000	TDD

n263 5G NR unlicensed

5G FWA – Fixed Wireless Access

- Point to Multipoint
- FR2 - 26, 28, 39, 41, 47 GHz,
- Substitution of ADSL, VDSL, SDSL, Coax, G.FAST, Optics
- 5G user data rates: experienced 100 Mbit/s, peak 20 Gbit/s
- 6G user data rates: experienced 1 Gbit/s, peak 1 Tbit/s

5G FWA mmWave – Last Mile



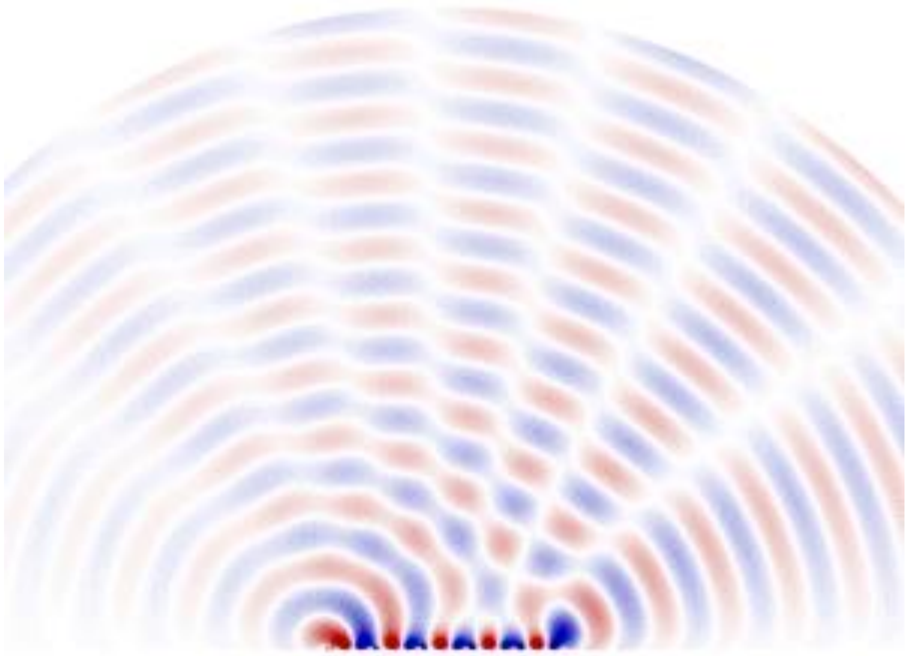
5G FWA – Fixed Wireless Access

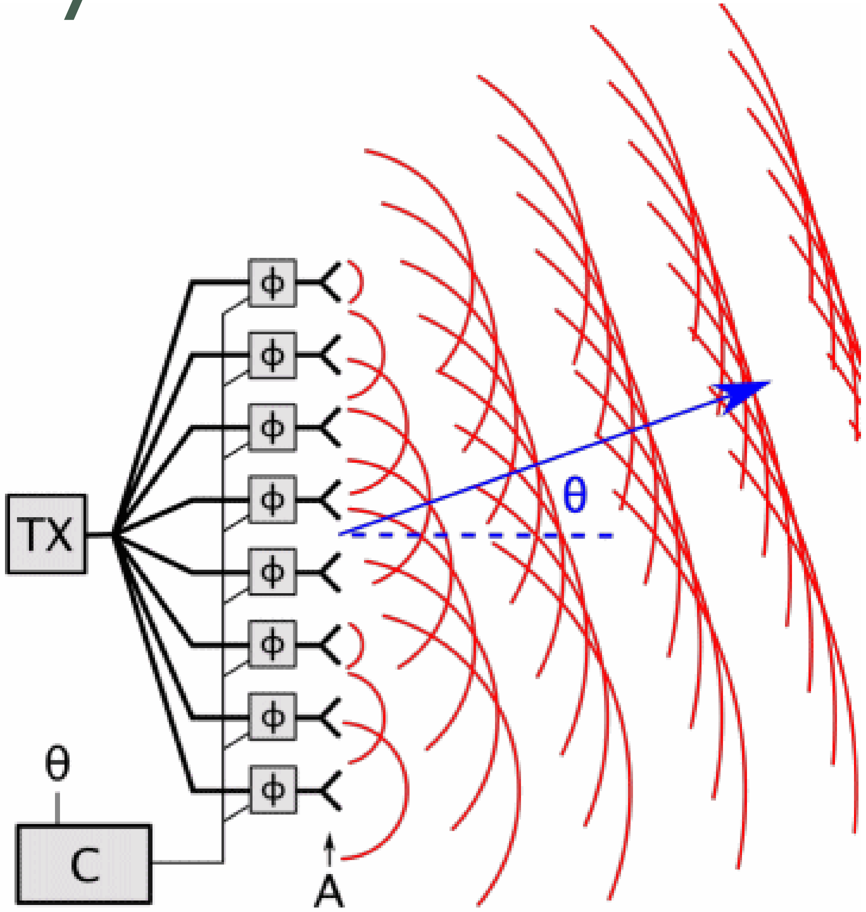
- 26 GHz
- Latency 11 ms
- Distance CPE form AU max. 1 km
- Download 900 Mbit/s / Upload 300 Mbit/s / excellent conditions
- Download 900 Mbit/s / Upload 150 Mbit/s / good conditions
- Download 500 Mbit/s / Upload 100 Mbit/s / bad conditions
- 120 users per sector

26 GHz

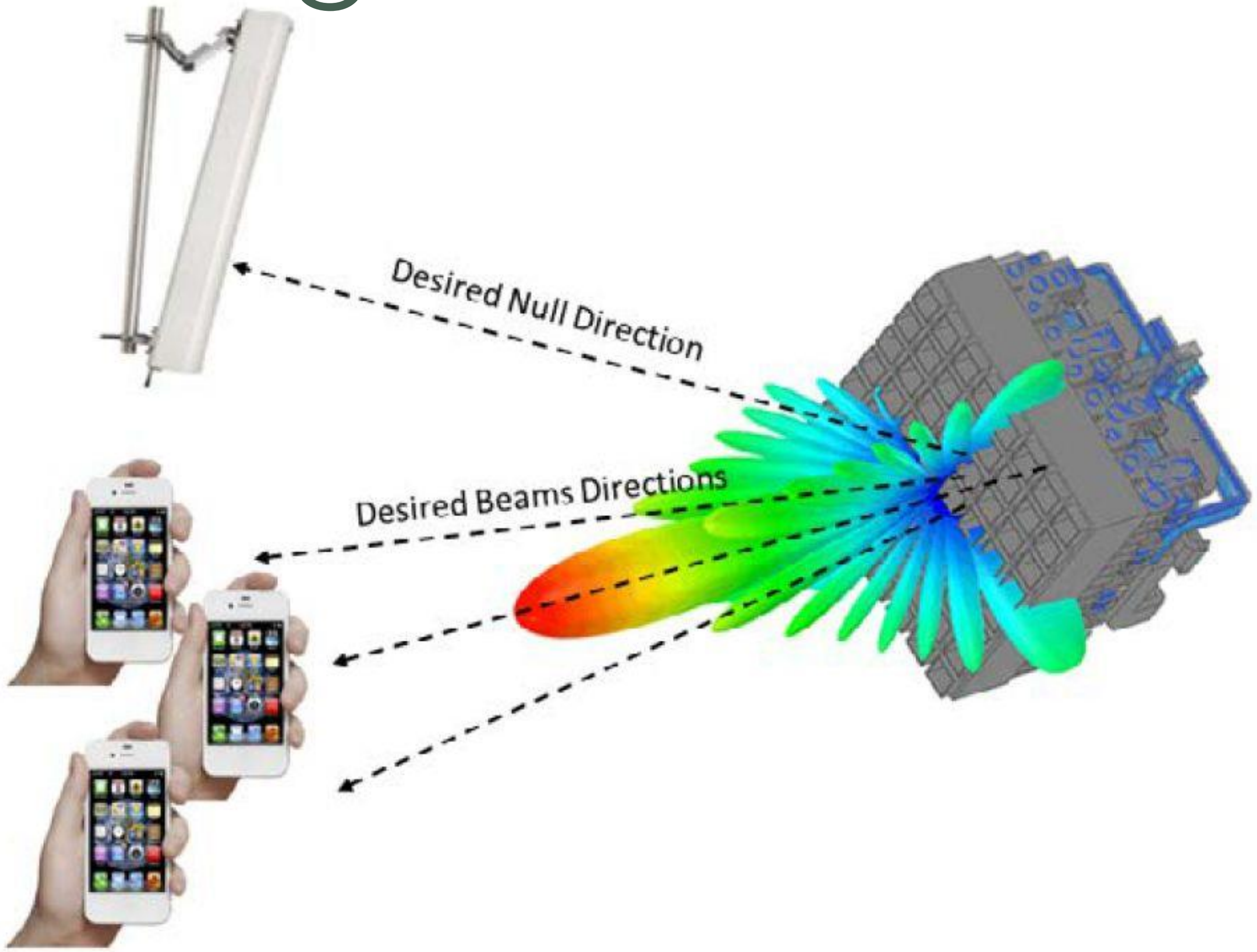
- pásmo n258 tedy 24,25–27,5 GHz šířka pásma 3,25 GHz
- ČTU uvolňuje 1 GHz od 26,5 do 27,5 GHz
- Kmitočty budou využívány v režimu TDD
- předpoklad 200 MHz kanály nebo jejich násobky
- Dle specifikace 3gpp 50 / 100 / 200 / 400 MHz

MIMO – Phased Array

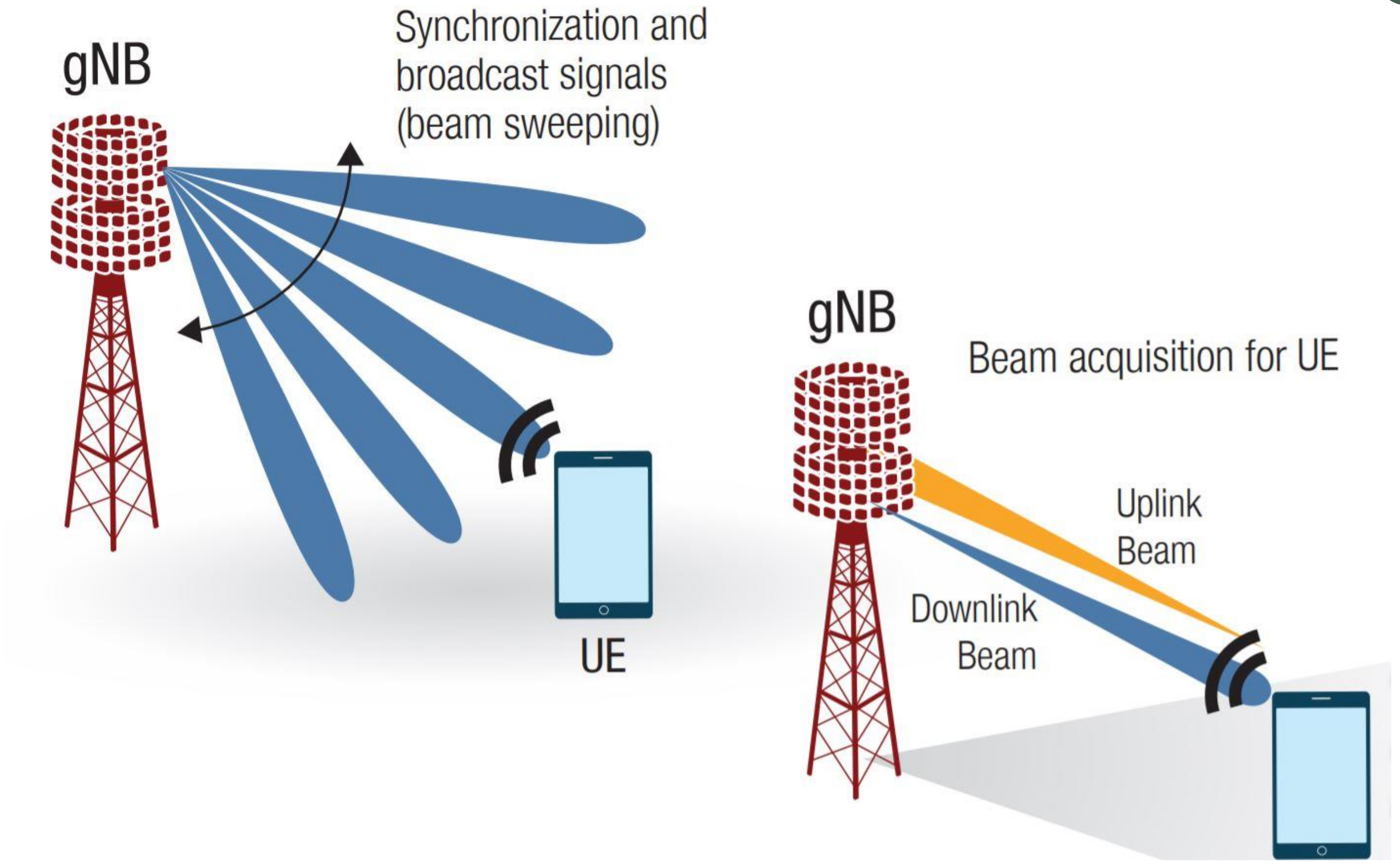




Beam forming

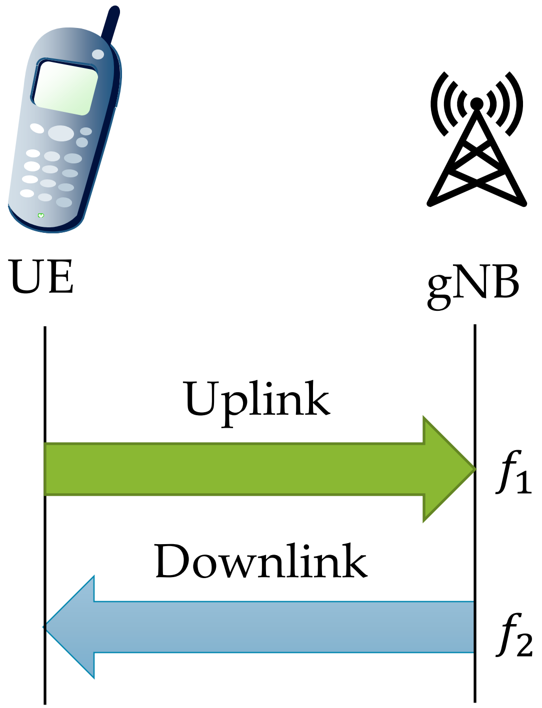


Massive MIMO & beam forming

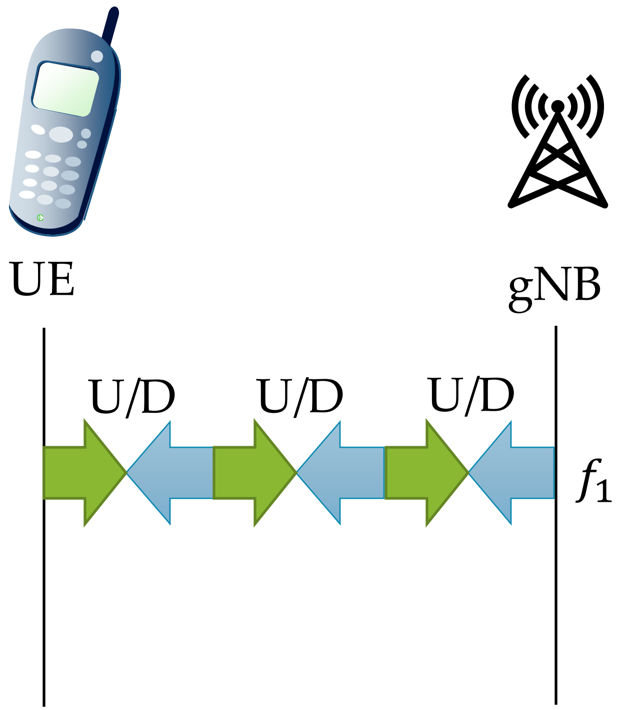


FDD vs TDD

Frequency Division Duplex – FDD
Time Division Duplex – TDD

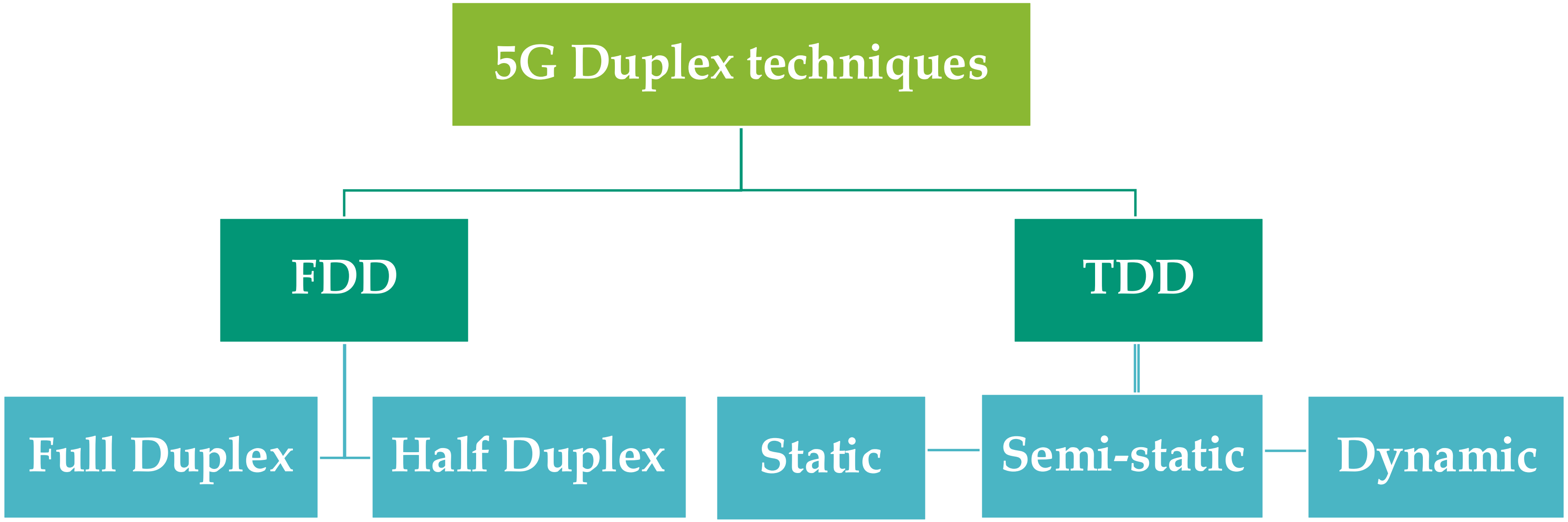


FDD



TDD

FDD & TDD duplex techniques



FDD vs TDD

Feature	5G NR FDD	5G NR TDD
Application	FDD version is used where both uplink and downlink **data rates are symmetrical.**	TDD version is used where both uplink and downlink **data rates are asymmetrical.**
Interference with neighboring Base Stations	Less	More
Deployment type	Not suitable for very dense environments.	It is used in very dense deployments with low-power nodes.
Frequency bands	It is preferable for lower frequency bands.	It is preferable for higher frequency bands usually above 3 GHz.
Channel response	Downlink and uplink channel responses would not match perfectly due to different frequency bands used in both these directions.	It matches and hence TDD delivers better performance in MIMO/Beamforming algorithms compare to FDD.

FDD vs TDD

- About 90 % of the frequency bands below 3 GHz that are reserved for mobile communications are organized as paired spectrum that separates downlink and uplink transmissions in the frequency domain.
- From 3.5 GHz - C-band only TDD
- Frequency Range 2 (> 24 GHz) mmWave only TDD

TDD FWA

- TDD period: 1 ms / 8 slots of 125 μs
- 625 μs for downlink
- 125 μs for downlink-to-uplink transition,
- 250 μs for Uplink

- Subcarrier spacing **SCS = 120 kHz** (i.e., Numerology 3, 1 slot (14 OFDM symbols) = 125 μs, 8 slots / 1 ms subframe – TDD period)
- TDD pattern: **DDDSU** , called 4:1 (or also 3:1:1)

Frame structure of TDD, DL:UL

Frame structure, DL:UL

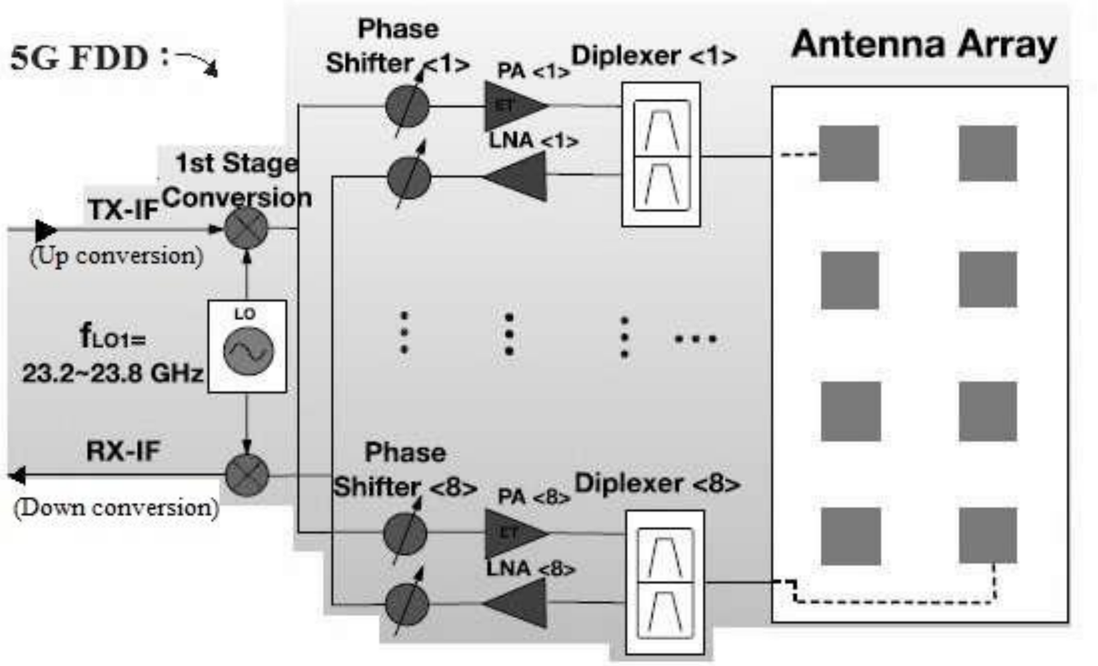
(Down link, Uplink, Signaling or Special slot)

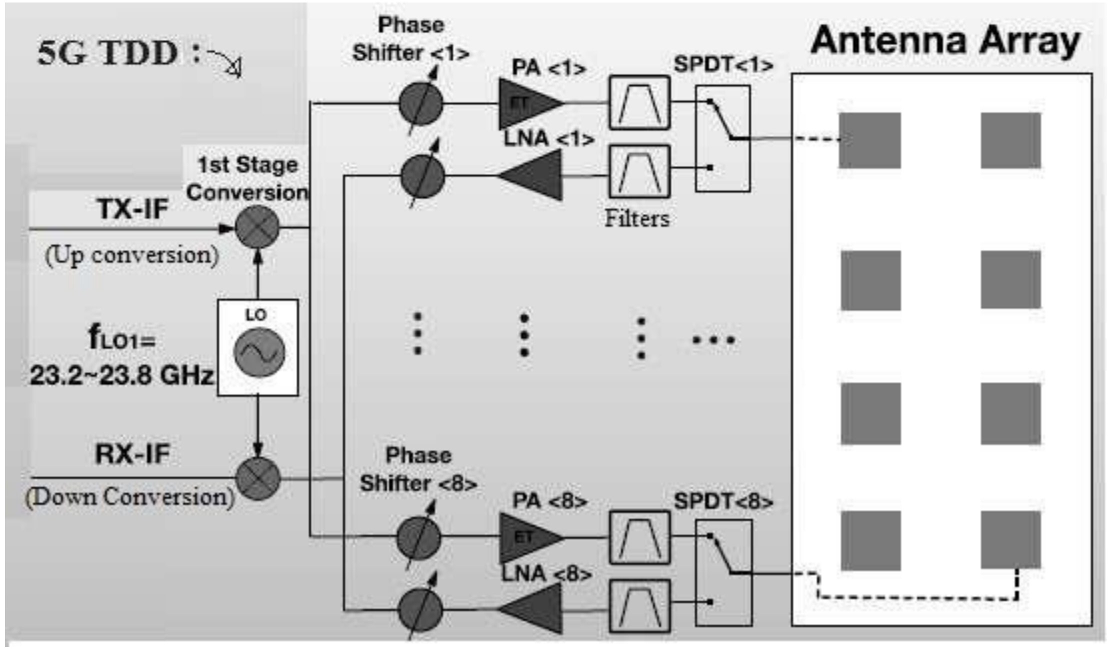
- **DDDSU**
- DDDDDDDSUU
- DDDSUUDDDD
- DSUUU

Guard period – guard interval

For TDD, in the Downlink , due to path distance DL signal can be delayed. Due to path distance , path delay is created. Delay can cause collision between UL and DL signals. The guard period provides enough time for DL delayed signal to arrive due to path distance, and also gives enough opportunity for (User Equipment) UE to receive UL timing advance command from the Base station.

FDD vs TDD


5G FDD :
Phase
Shifter <1>
PA <1>
Diplexer <1>
Antenna Array
LNA <1>
1st Stage
Conversion
TX-IF
(Up conversion)
LO
fLO1=
23.2~23.8 GHz
RX-IF
(Down conversion)
Phase
Shifter <8>
PA <8>
Diplexer <8>
LNA <8>


5G TDD :
Phase
Shifter <1>
PA <1>
SPDT<1>
Antenna Array
LNA <1>
1st Stage
Conversion
TX-IF
Filters
(Up conversion)
LO
fLO1=
23.2~23.8 GHz
RX-IF
(Down Conversion)
Phase
Shifter <8>
PA <8>
SPDT<8>
LNA <8>

Synchronization

- GNSS – GPS, GALILEO, GLONASS nebo PTP
- Časová reference je navázána na UTC a počátek rádiového rámce začíná celou sekundu – International Atomic Time (TAI)
- Dle ETSI TS 138 401 (3GPP TS 38.401)
- Požadavky: přednost fázové a časové synchronizace je ±1,5 μs

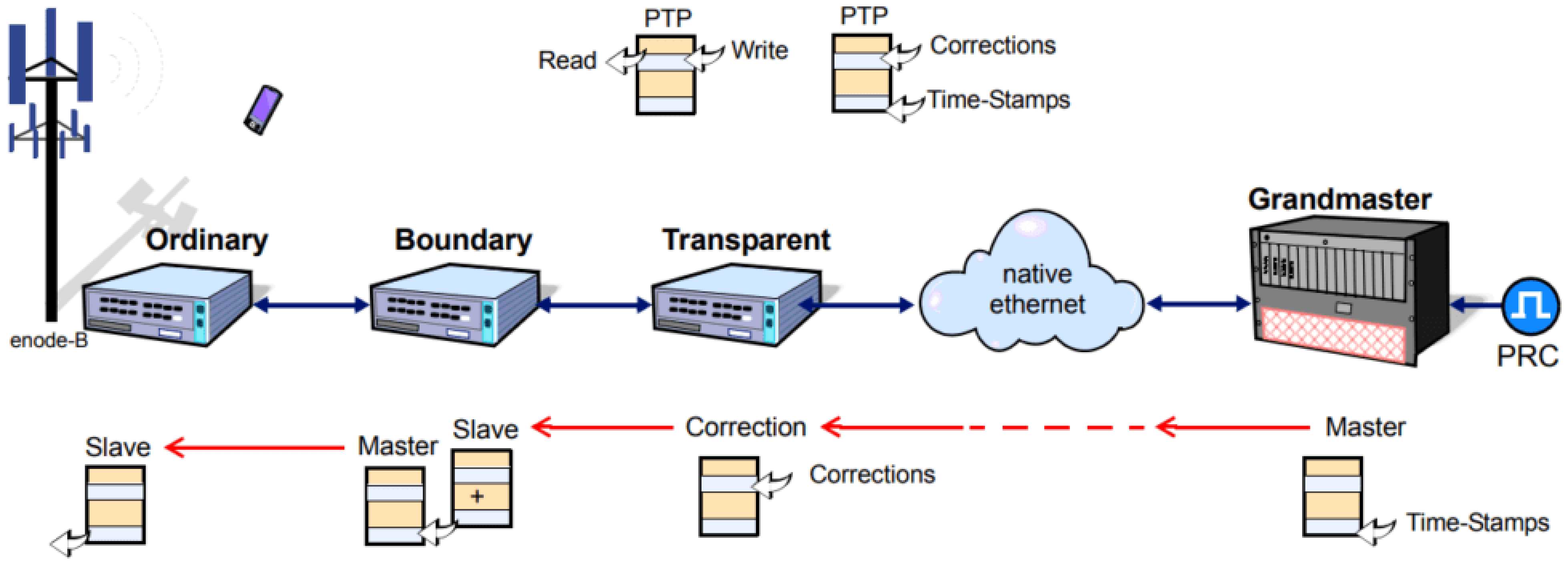
NTP vs PTP

- NTP from 1985 (40 years ago) current version 4
- NTP precision around 10 ms, in local network < 1 ms
- Precision Time Protocol (PTP) from 2002 IEEE 1588-2002
- IEEE 1588-2008, also known as PTP Version 2 (PTPv2) is not backward compatible with original 1588-2002
- IEEE 1588-2019 (PTPv2.1) includes backward-compatible improvements to the IEEE 1588-2008
- PTP transport UDP/IP or ethernet (PTP over bare IEEE 802.3 Ethernet using Ethertype (0x88F7)
- PTP precision around 10 µs, in local network < 1 µs (measured in nanoseconds)

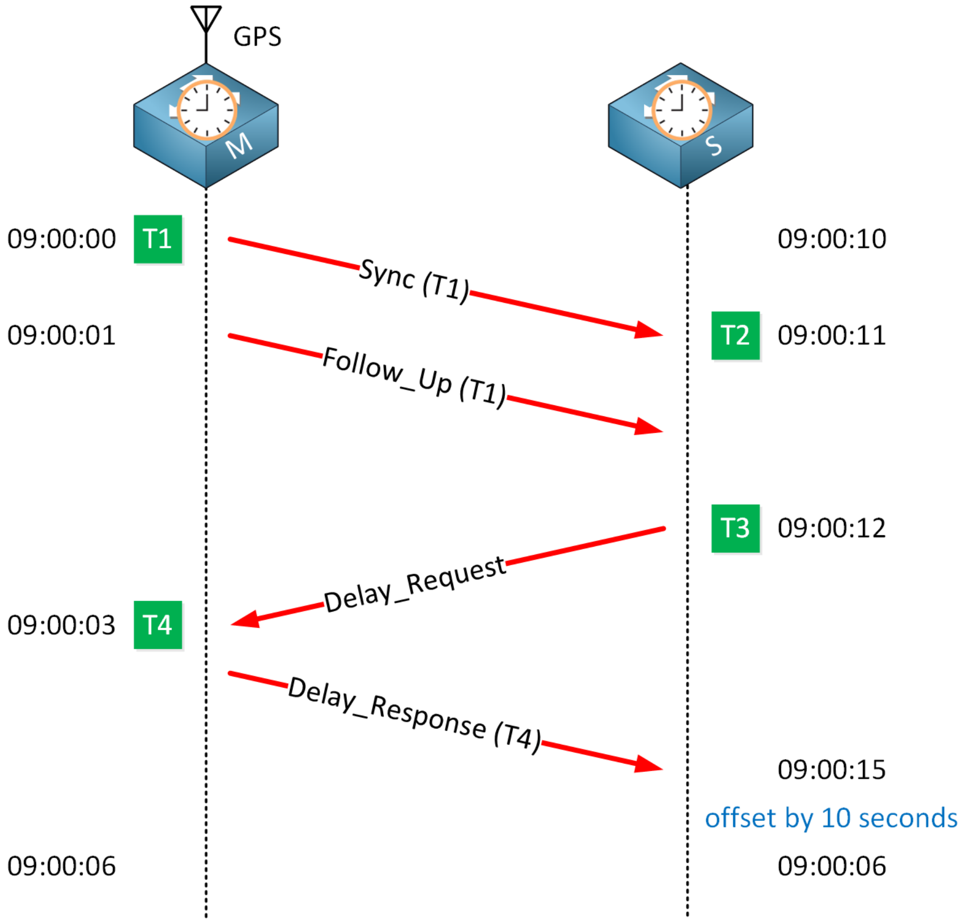
PTP Device Types

- Master Clock (MC): A master clock provides accurate time stamping to slaves clocks collocated at the downstream side.
- Grand Master (GM): A grandmaster is a the master clock situated at root timing, therefore is the clock reference, transmitting time information to the clocks of its segment. Write time stamps and responds time request from other clocks
- Transparent Clocks (TC): A transparent clocks pass through PTP messages adding in the correction field the time spent packets when traversing the device. Write corrections
- Boundary Clock (BC): A boundary clock has multiple network connections, works as slave upstream and as master downstream. Then it bridges synchronization from one segment to another. Read/Write time stamps
- Ordinary Clock (OC): It is a clock device with a single port connection that can play de role of master or slave depending on its position in the network. Read/Write time stamps.

PTP Device Types



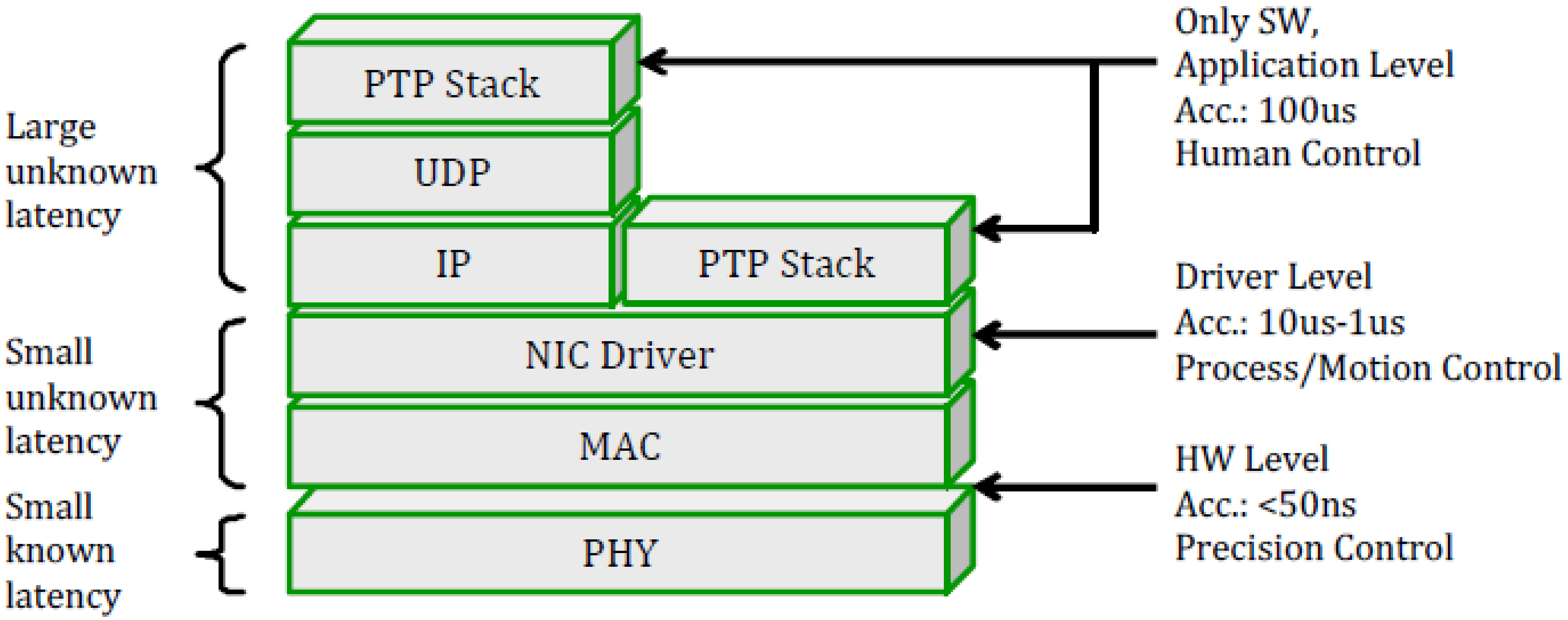
PTP (Precision Time Protocol)



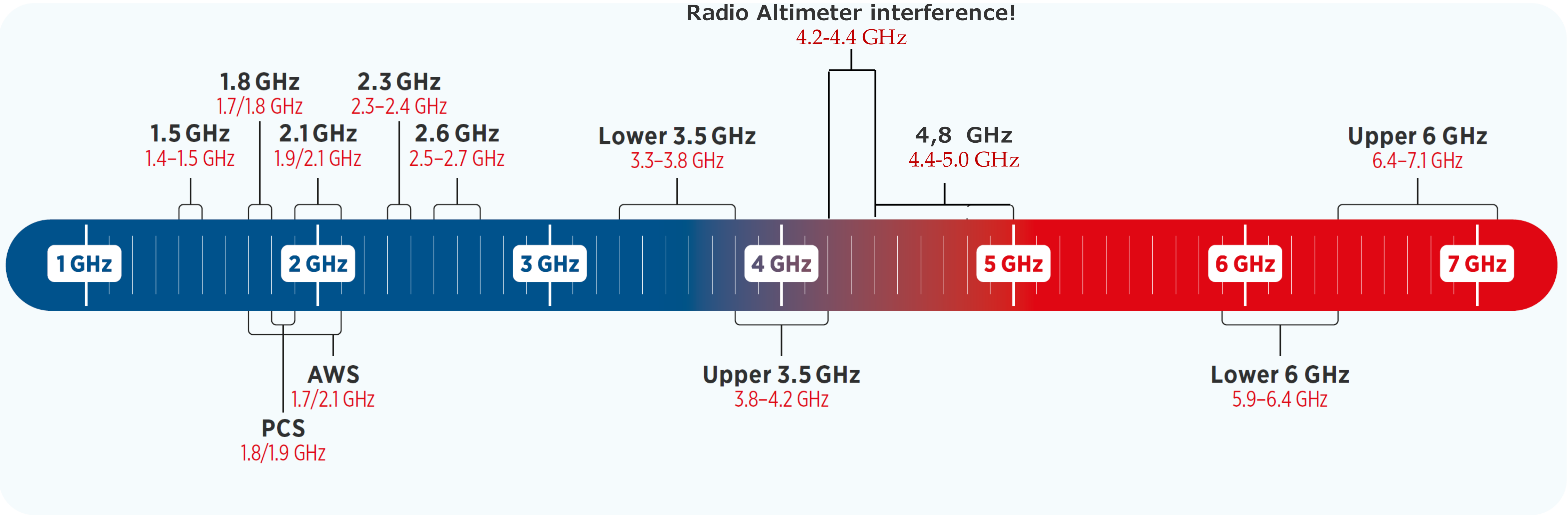
T2 – T1 = Delay + Offset
T4 – T3 = Delay – Offset
Offset = ((T2 – T1) – (T4 – T3)) / 2
Delay = ((T2 – T1) + (T4 – T3)) / 2

11 – 0 = Delay + Offset = 11
3 – 12 = Delay – Offset = -9
Offset = ((11) – (-9)) / 2 = 10
Delay = ((11) + (-9)) / 2 = 1

PTP (Precision Time Protocol)



5G Spectrum



Radio Altimeter interference!
4.2-4.4 GHz
1.8 GHz
1.7/1.8 GHz
2.3 GHz
2.3–2.4 GHz
1.5 GHz
1.4–1.5 GHz
2.1 GHz
1.9/2.1 GHz
2.6 GHz
2.5–2.7 GHz
Lower 3.5 GHz
3.3–3.8 GHz
4,8 GHz
4.4-5.0 GHz
Upper 6 GHz
6.4–7.1 GHz
1 GHz
2 GHz
3 GHz
4 GHz
5 GHz
6 GHz
7 GHz
AWS
1.7/2.1 GHz
PCS
1.8/1.9 GHz
Upper 3.5 GHz
3.8–4.2 GHz
Lower 6 GHz
5.9–6.4 GHz

End

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