5G channels and signals

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Technical module: Planning

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II. 5G New Radio(NR)
III. 5G End to end architecture
IV. Design and key radio functionalities
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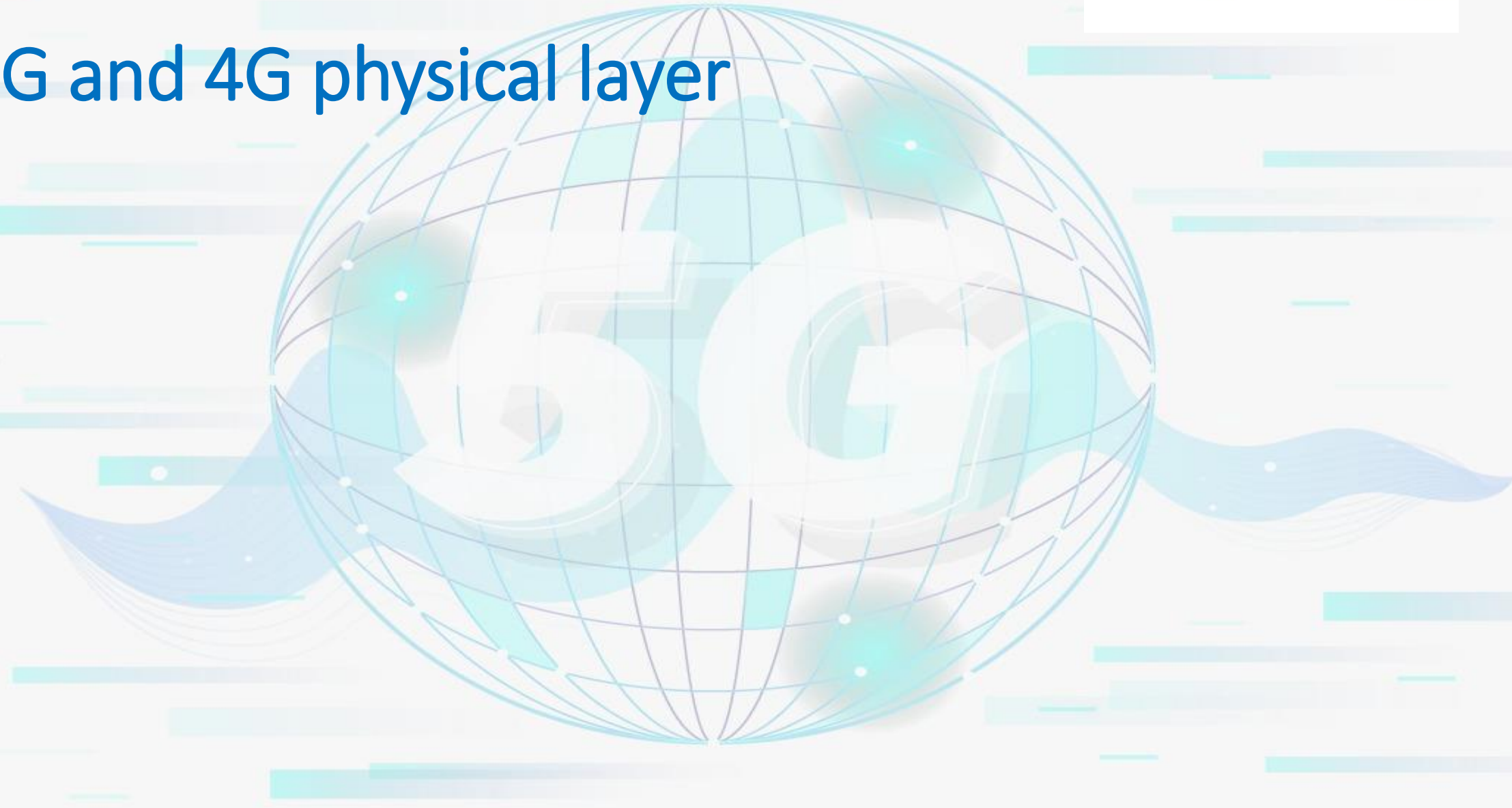
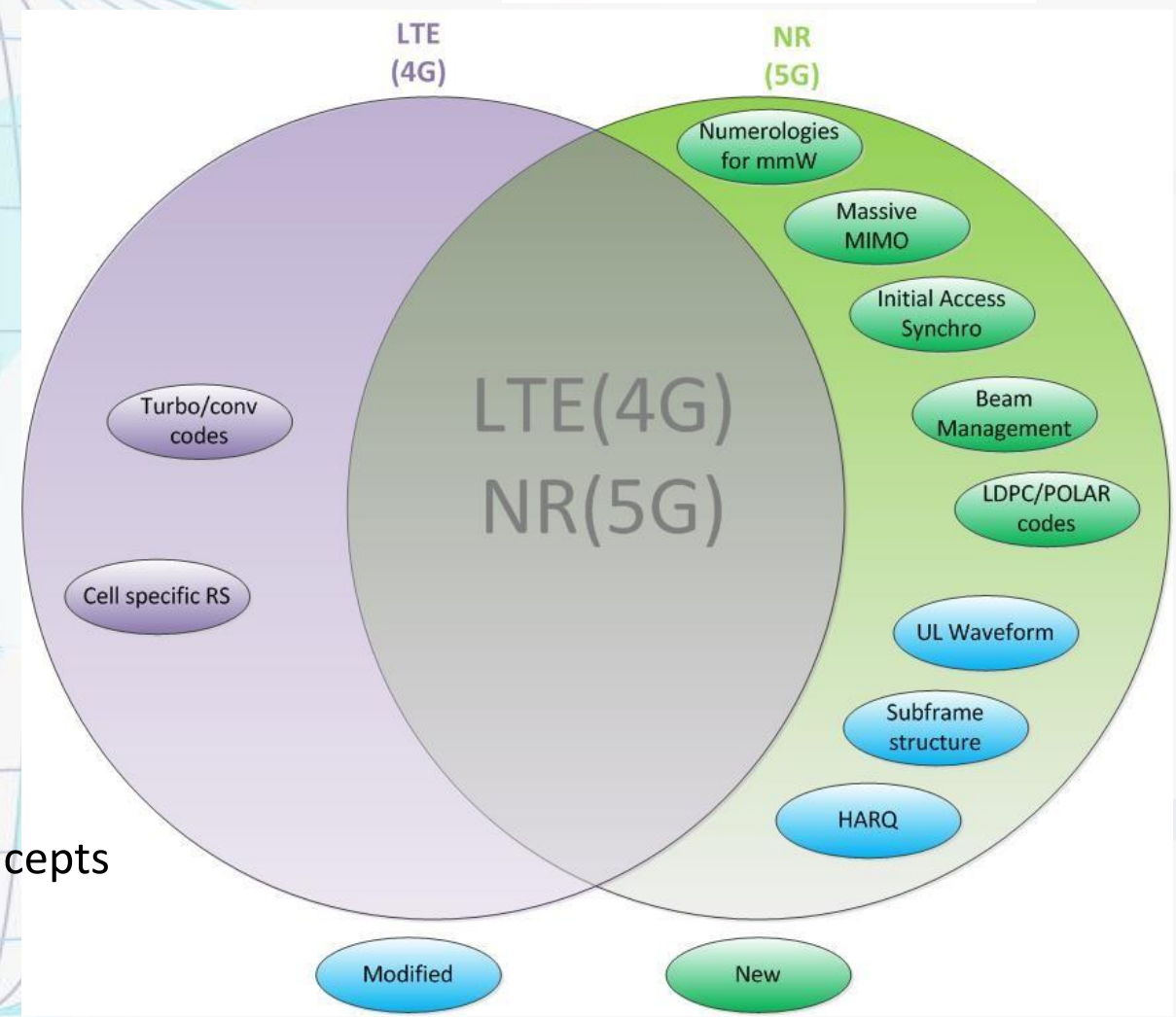
5G and 4G physical layer



5G and 4G physical layer

- 5G NR, inherits many concepts and techniques from LTE
- 5G need a very flexible layer 1 and layer 2 design to :
  - ✓ Address new services
  - ✓ Support new frequencies
  - ✓ Support wider bandwidth
  - ✓ Support high number of antennas
- 5G is a collection of optimized 4G techniques with new concepts



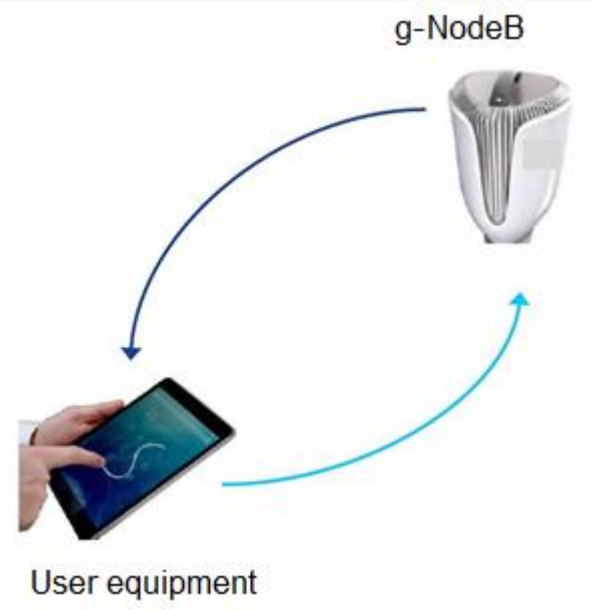
Main Physical Layer Differences

	LTE	5G
Use cases	Mobile broadband access (MTC later)	More use cases: eMBB, mMTC, URLLC
Latency	~10 ms	<1 ms
Band	Below 6 GHz	Up to 60 GHz
Bandwidth	Up to 20 MHz	Up to 100 MHz below 6 GHz Up to 400 MHz above 6 GHz
Subcarrier spacing	Fixed	Variable
Freq allocation	UEs need to decode the whole BW	Use of bandwidth parts
"Always on" signals	Used: Cell specific RS, PSS,SSS, PBCH	Avoid always on signals, the only one is the SS block

5G DL physical Channels

5G Downlink Physical channels

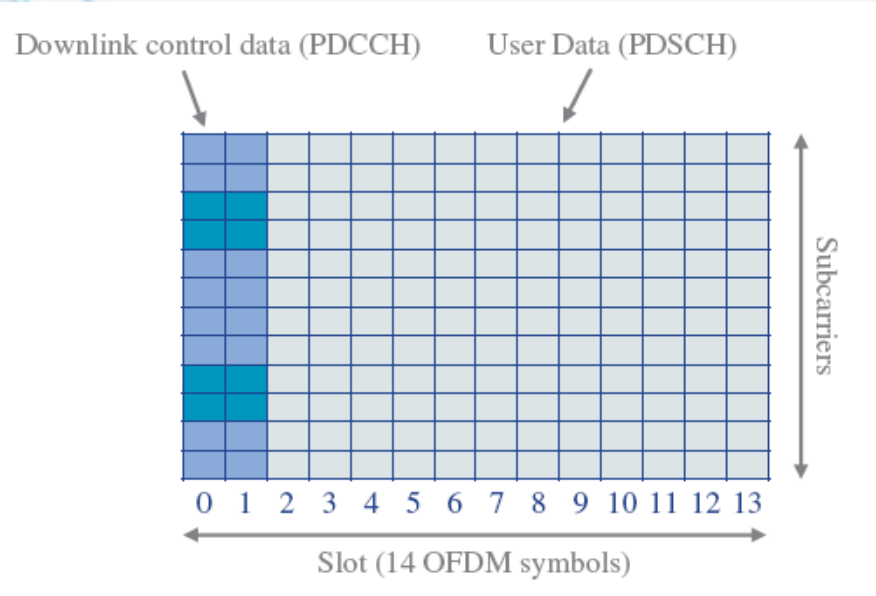
- A downlink physical channel corresponds to a set of resource elements carrying information originating from higher layers.
- Downlink Physical channels in 5G:
  - ✓ Physical Broadcast channel (PBCH).
  - ✓ Physical Downlink Control Channel (PDCCH).
  - ✓ Physical Downlink Shared Channel (PDSCH).
  - ✓ And No PCFICH or PHICH needed in 5G NR



5G Downlink Physical channels

- Physical downlink control channel (PDCCH): that carries DCI for downlink control information (DCI)
- Physical Downlink Shared Channel (PDSCH): that carries the user data and System information for user
  - ✓ The PDCCH is place before the PDSCH
- Physical broadcast channel (PBCH) which carries the necessary system information to enable a UE to access the 5G network.

=> Keep in mind that PBCH is linked to signals PSS (Primary Synchronization Signal) and SSS (Secondary Synchronization Signal)



5G Downlink Signals

- DL Physical signals corresponds to a set of resource elements used by the physical layer but does **not** carry information originating from higher layers.

Downlink Physical signals in 5G:

- ✓ Primary Synchronization Signal (PSS).
- ✓ Secondary Synchronization Signal (SSS).
- ✓ Channel State Information Reference Signal(CSI-RS).
- ✓ Phase-Tracking Reference Signal (PT-RS).
- ✓ Demodulation reference signals (DM-RS).

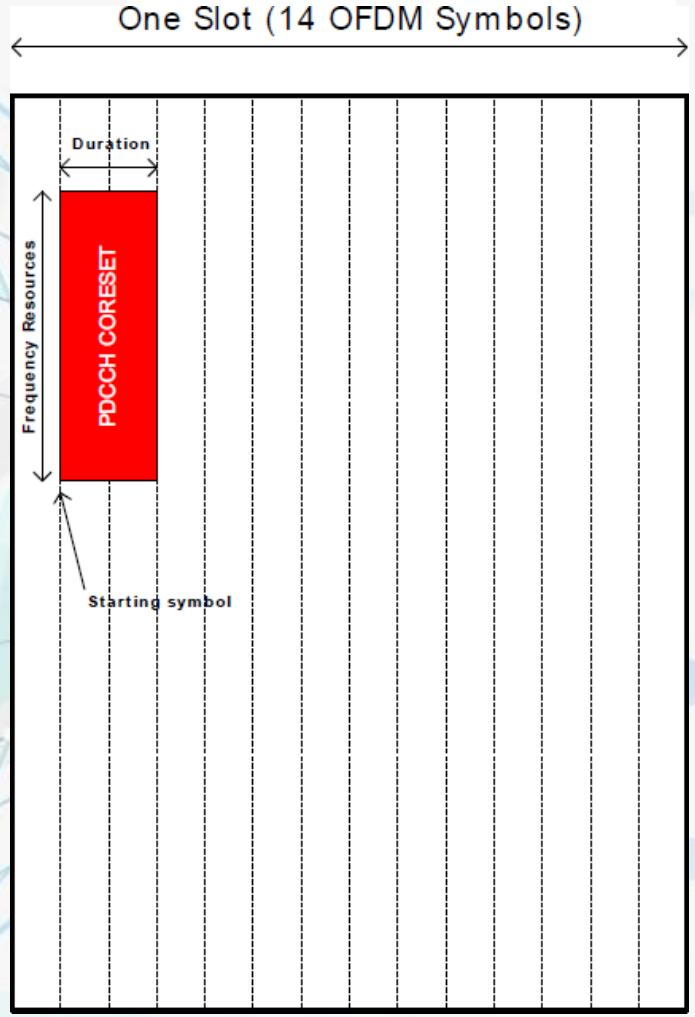
=> In LTE we had only CRS (common reference signal)

5G Downlink Signals

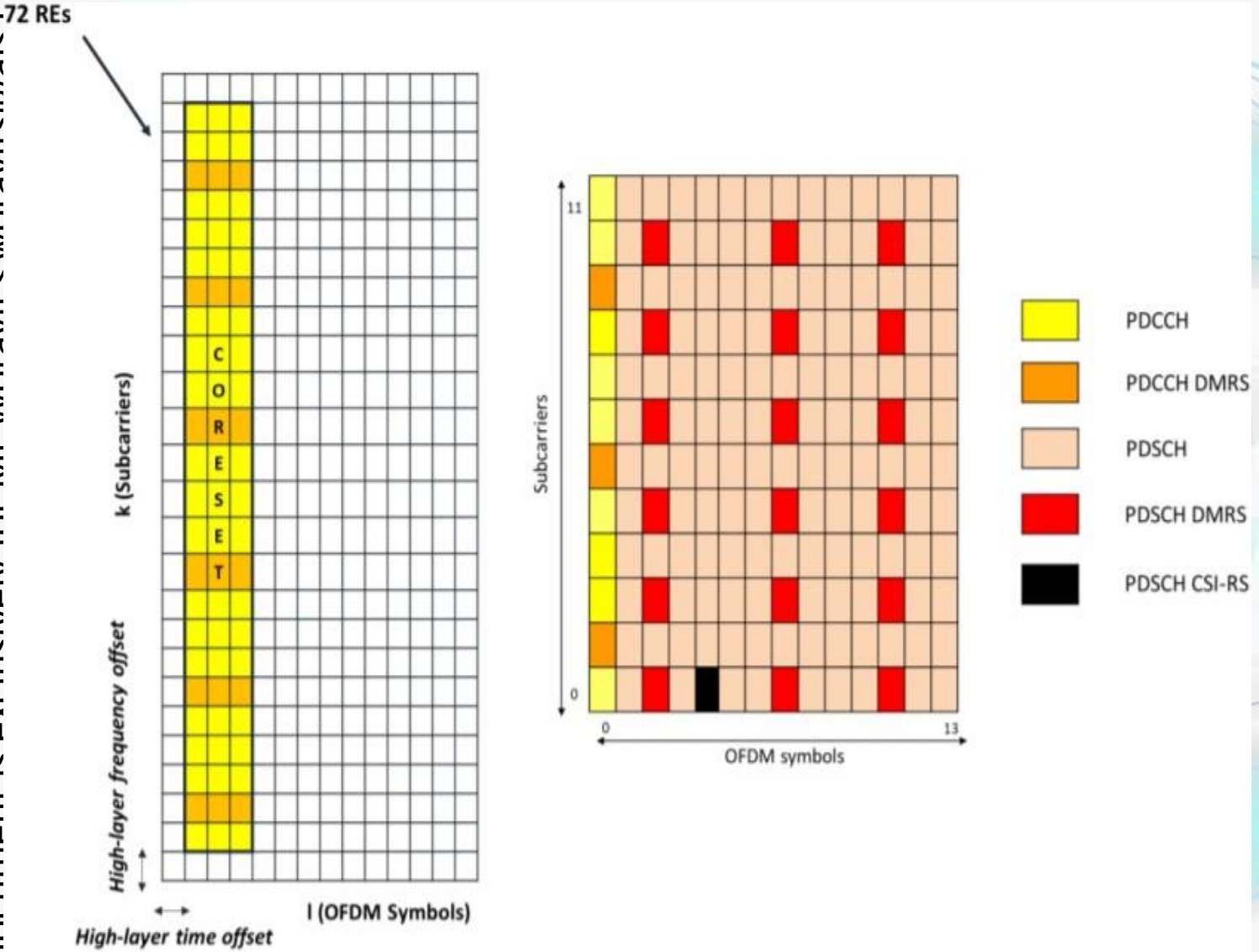
	PDSCH (5G)	PDSCH (LTE)	PDCCH (5G)	PDCCH (LTE)
Purpose	Transmit DL Data	Transmit DL Data	L1/L2 Control channel	L1/L2 Control channel
Waveform	OFDM	OFDM	OFDM	OFDM
Bandwidth	Numerology dependent	1.4/3/5/10/15/20 MHz	Localized in BWP	Spread out in the entire bandwidth
Reference signals	Only UE specific signals (DMRS)	Cell specific or UE specific (Rel. 10)	UE specific (DMRS)	Cell specific (CRS)
Modulation	Up to 256QAM	Up to 256 QAM	QPSK	QPSK
Coding scheme	LDPC	Turbo	Polar	TBCC

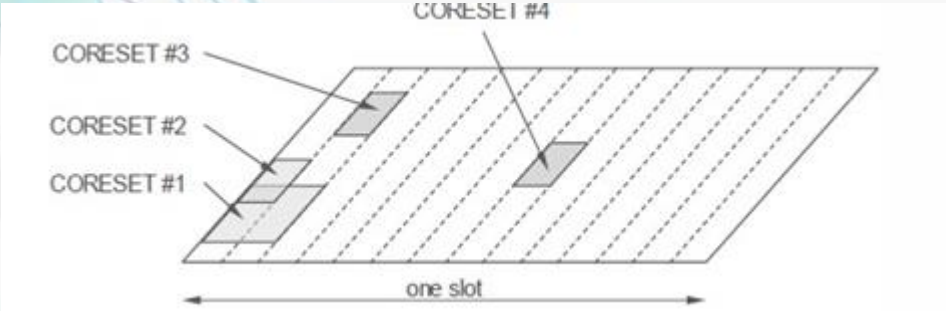
PDCCH CORESET

- CORESET stands for Control Resource Set
- CORESET is defined as a set of REGs under a given numerology.
- Time-frequency region where the UE monitors for PDCCH transmission.
- Configured by UE-specific higher-layer signaling:
  - ✓ Starting OFDM symbol (OFDM symbol #0, #1 or #2).
  - ✓ Time duration (maximum duration of 3 OFDM symbols).
  - ✓ Not necessarily located at the beginning of the slot.
  - ✓ The minimum CORESET length is equal to 6 RBs=6 x 12 REs/RB = 72 REs



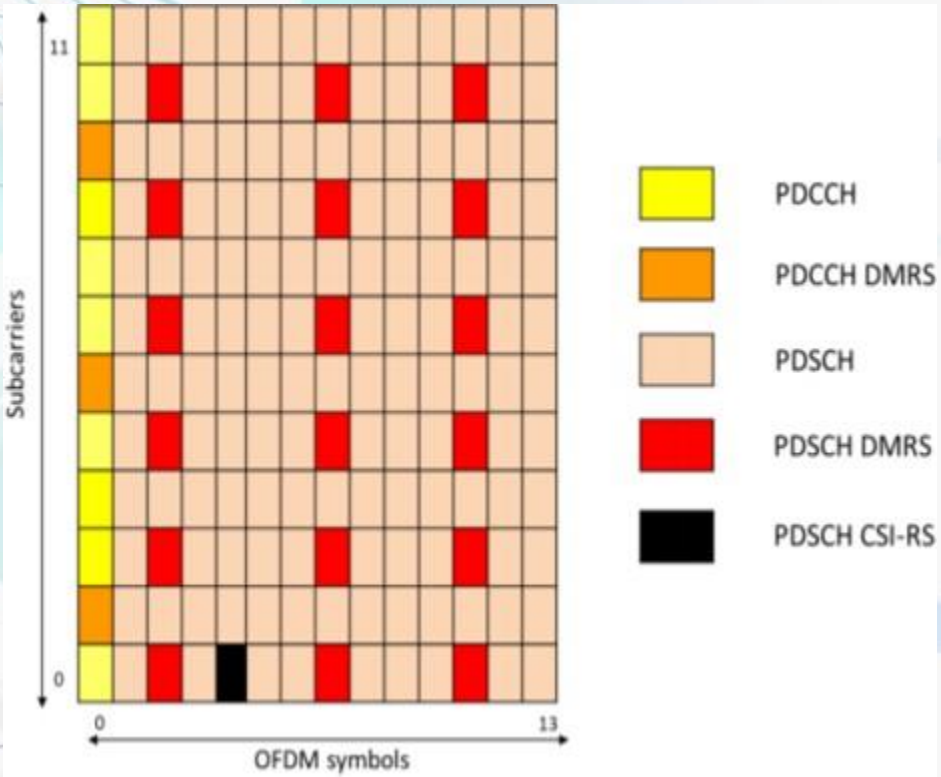
5G Downlink Channels: PDCCH

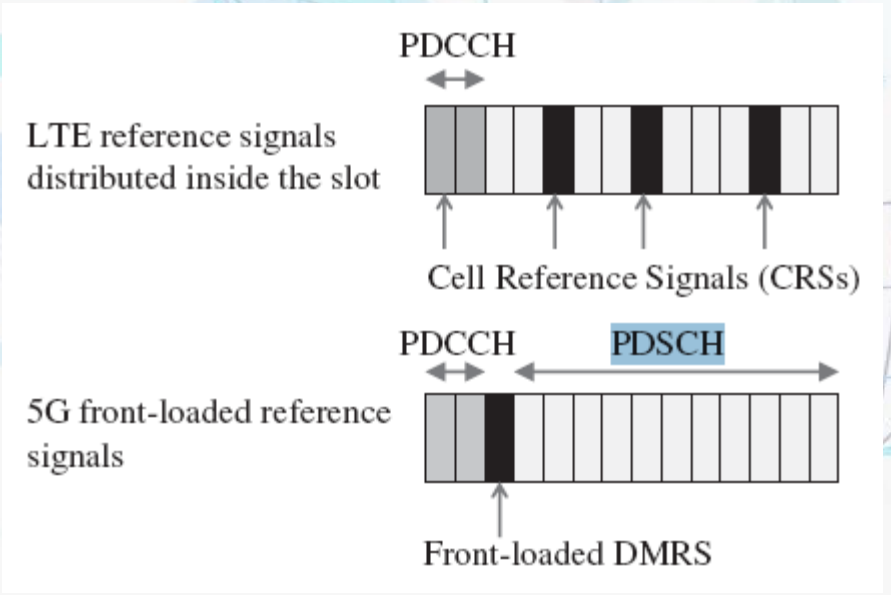




5G Downlink Channels: PDSCH

- The number of RBs associated to PDSCH transmissions depends on the available bandwidth and numerology.
- As for PBCH and PDCCH, PDSCH also includes DMRS in order to ease the demodulation process.
- PDSCH also includes PT-RS and CSI-RS.



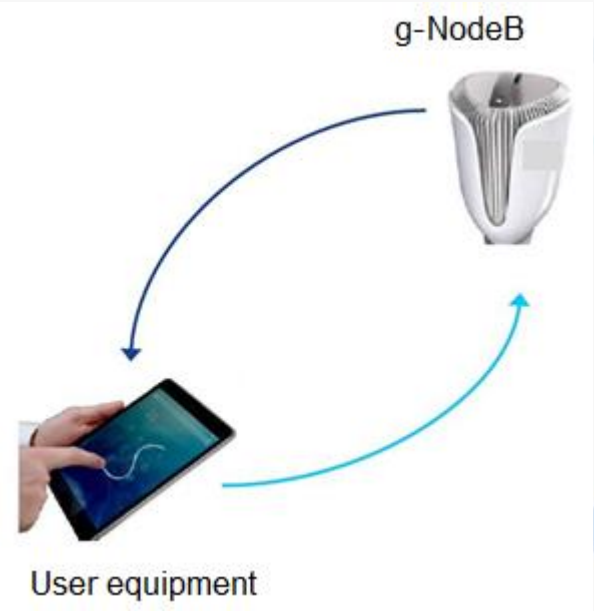


5G UL physical Channels

5G Uplink Physical channels

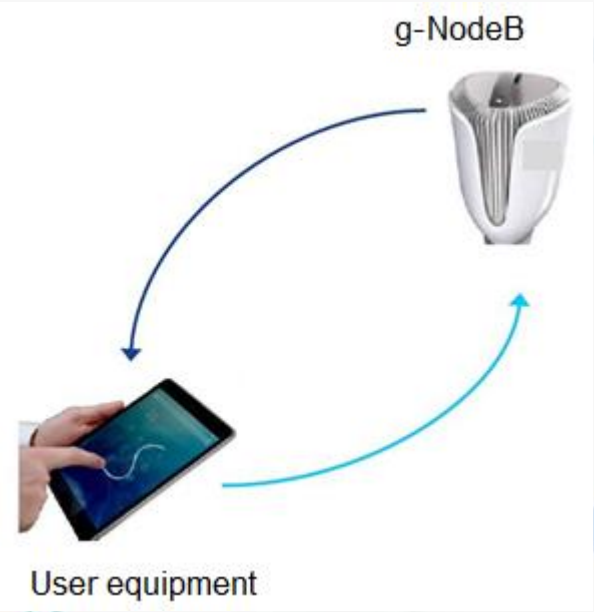
- An uplink physical channel corresponds to a set of resource elements carrying information originating from higher layers.

- Uplink Physical channels:
  - ✓ Physical Uplink Shared Channel (PUSCH).
  - ✓ Physical Uplink Control Channel (PUCCH).
  - ✓ Physical Random Access Channel (PRACH).



5G Uplink Channels

- Physical Uplink Control Channel (PUCCH):
  - ✓ Used for uplink control information, which includes: HARQ feedback acknowledgments, scheduling request, and downlink channel-state information for link adaptation.
- Physical Uplink Shared Channel (PUSCH):
  - ✓ Used for uplink data transmission (by a UE).
- Physical Random Access Channel (PRACH):
  - ✓ Used by a UE to request connection setup referred to as random access.



5G Uplink Signals

- An uplink physical signal is used by the physical layer but does not carry information originating from higher layers.
- Uplink Physical signals:
  - ✓ Demodulation reference signals (DM-RS)
  - ✓ Phase-tracking reference signals (PT-RS)
  - ✓ Sounding reference signal (SRS)

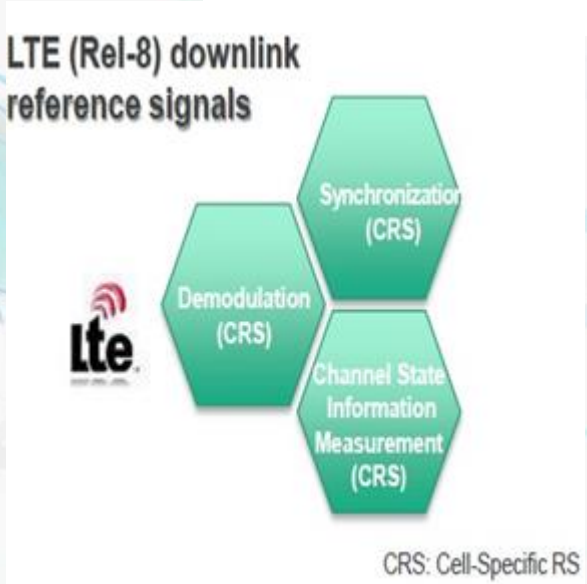
Comparison of UL channels with LTE

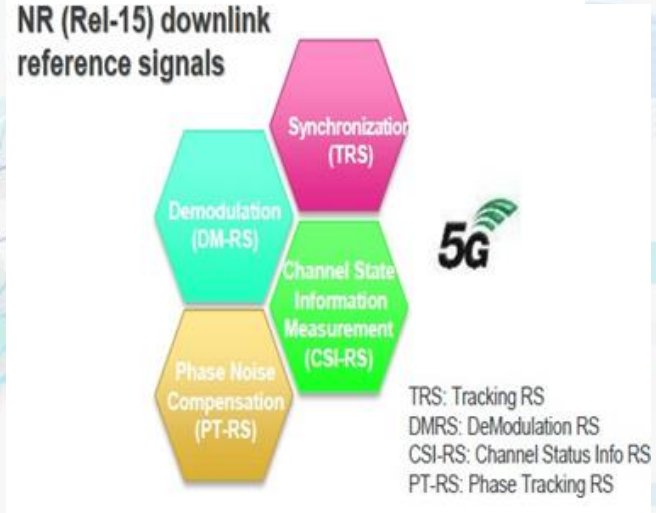
	PUSCH (5G)	PUSCH (LTE)	PUCCH (5G)	PUCCH (LTE)
Purpose	Transmit UL Data	Transmit UL Data	L1/L2 Control information	L1/L2 Control information
Waveform	OFDM or SC-FDMA	SC-FDMA	Filtered OFDM or SC-FDMA	SC-FDMA
Bandwidth	Depend on numerology	1.4/3/5/10/15/20	Many flexible formats in time/freq.	1 RB in freq. 14 symbols time
Modulation	Up to 256 QAM	Up to 256 QAM	QPSK	QPSK
Coding scheme	LDPC	Turbo	RM/Polar	RM/TBCC

5G reference Signals

5G NR reference signals

- The physical signals are reference signals used for different purposes:
  - ✓ Demodulation,
  - ✓ Channel estimation,
  - ✓ Synchronization
  - ✓ Channel-state information.
- LTE has a only one type of reference signal design: CRS
  - ✓ Limits flexible network deployments,
- NR downlink reference signals can be flexibly adapted and is sent only when necessary





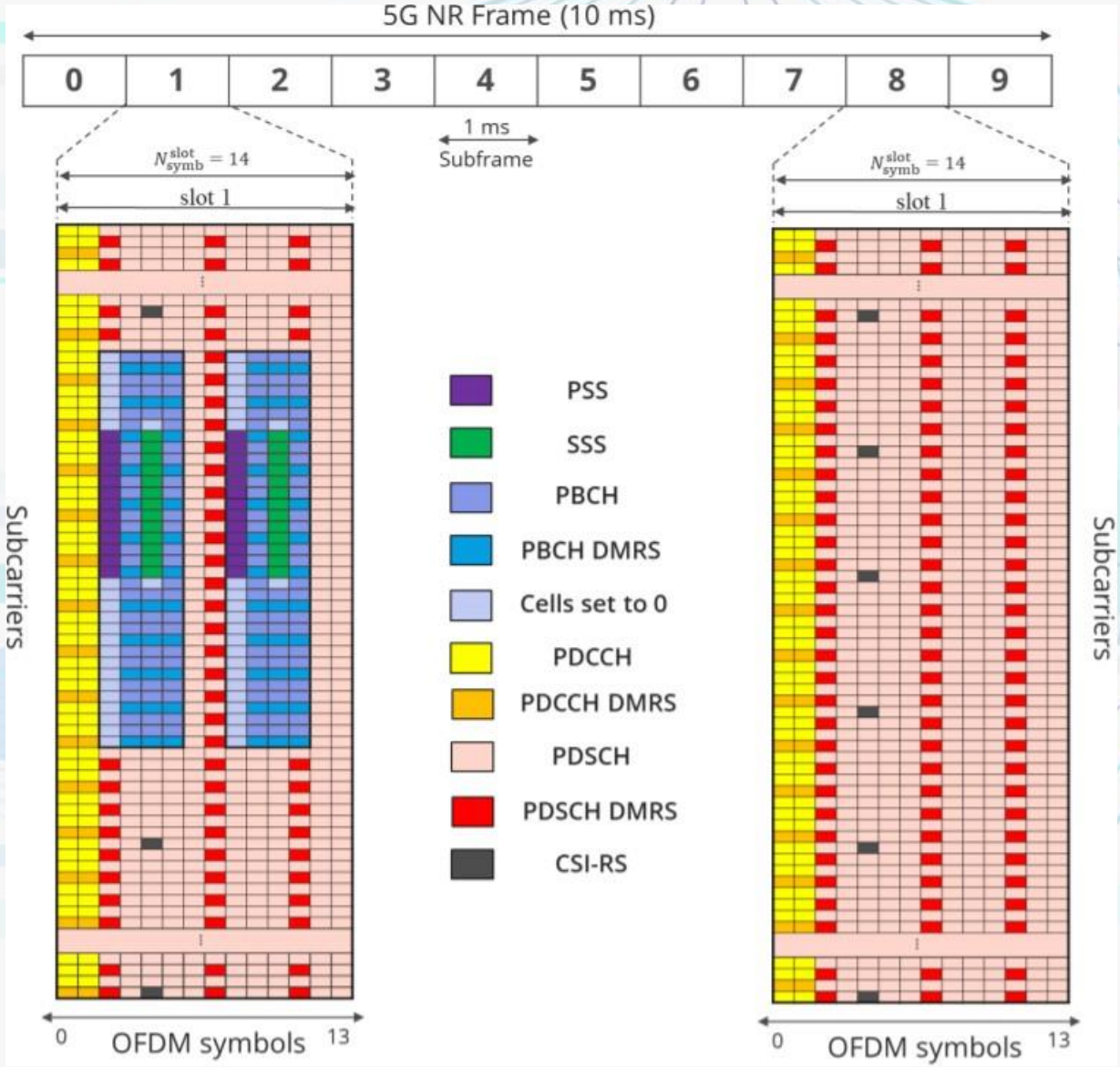
5G NR reference signals

- Demodulation Reference Signal (DM-RS):
  - ✓ Estimate channel for demodulation. Placed at the beginning of slot.
- Phase Tracking Reference Signal (PT-RS):
  - ✓ Estimate phase noise at high carrier frequencies
- Channel State Information Reference Signal (CSI-RS):
  - ✓ Beam management and uplink power control
- Sounding Reference Signal (SRS):
  - ✓ Transmitted in uplink to measure channel for scheduling and link adaptation

Demodulation Reference Signals (DM-RS)

- DMRS is used by the receiver to produce channel estimates for demodulation of the associated physical channel.
- The design of DMRS is specific for each physical channel – PBCH, PDCCH, PDSCH, PUSCH, and PUCCH.
- In low latency communication, DMRS is used in the beginning of the slot

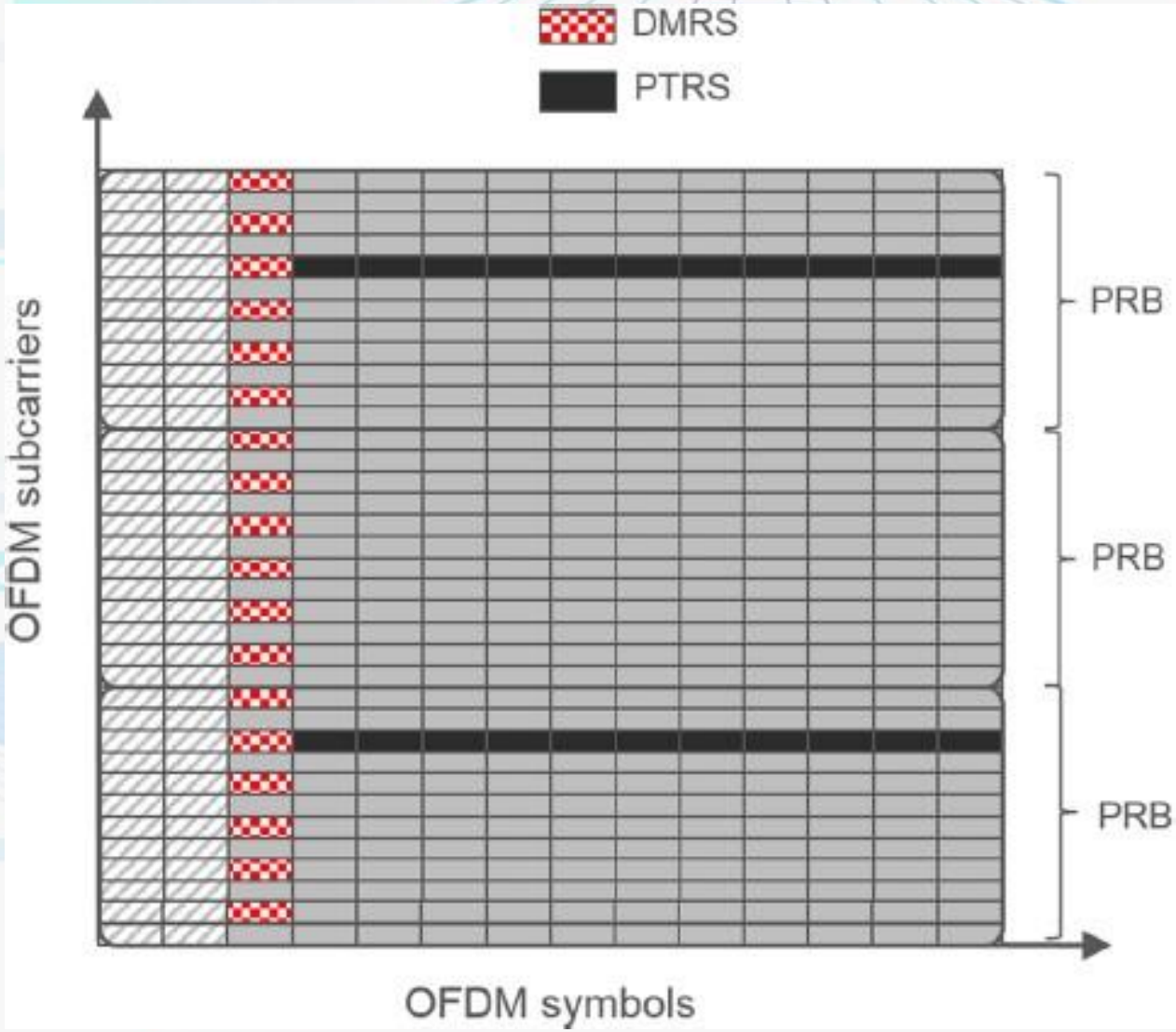
Demodulation Reference Signals (DM-RS)



Phase-tracking reference signal (PT-RS)

- PT-RS is designed for compensation of downlink/uplink phase noise compensation.
- PTRS is used for tracking the phase of the local oscillator at the receiver and transmitter.
- PTRS plays an important role here to minimize the effect of the oscillator phase noise on system performance.
- PTRS is associated with one DMRS port during transmission.

Phase-tracking reference signal (PT-RS)



Channel-State Information Reference Signals (CSI-RS)

- CSI-RS is a downlink reference signal which is used For:
  - ✓ CSI acquisition,
  - ✓ beam management,
  - ✓ time/frequency tracking
  - ✓ uplink power control.
- UE receives this signal to estimate the channel quality and report channel quality information back to the gNB.
- It has a very flexible design in order to support diverse use cases.

Channel-State Information Reference Signals (CSI-RS)

Three different types of CSI-RS is supported: Periodic, aperiodic, and semi-persistent CSI-RS.

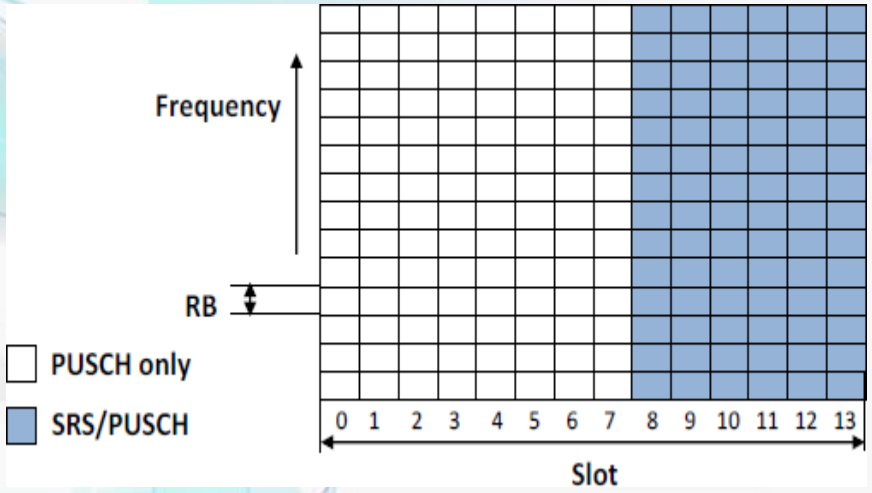
A resource can be configured with up to 32 ports.

Resource usually occupies 1/2/4 OFDM symbols

	Periodic CSI-RS	Aperiodic CSI-RS	Semi-Persistent CSI-RS
Orthogonal Ports	Up to 32	Up to 32	Up to 32
Time domain behavior	Periodic transmission once configured	Single transmission when triggered	Periodic transmission once activated until deactivated
Activation /Deactivation	RRC signaling	L1 signaling	MAC CE
Characteristics	No L1 overhead	Low latency	Hybrid of periodic and aperiodic CSI-RS

Sounding Reference Signal (SRS)

- The SRS is transmitted in uplink to perform CSI measurements mainly for scheduling and link adaptation
- It is equivalent to CSI-RS for uplink.
- Up to 6 OFDM symbols for SRS in 5G (Vs 1 OFDM symbol in 4G)



Conclusion

- 5G NR inherits many concepts and techniques from LTE
- 5G Downlink Physical channels are : PBCH, PDCCH, PDSCH
- CORESET was introduced in 5G with PDCCH to allocate control channels only in specific resource blocks
- 5G Uplink Physical channels: PUSCH, PUCCH, PRACH
- 5G reference signals in UL or DL: PSS, SSS, CSI-RS, PT-RS, DM-RS, SRS

Thank You

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