5G Frame Structure and Frequency structure

Release 15 TS 38.211

Terminologies

- T_S : Sampling time
- μ : Numerology index
- BWP : Bandwidth part
- CRB : Common Resource block
- PRB : Physical Resource Block
- SCS : subcarrier spacing
- CP : cyclic prefix
- CBW : Carrier Bandwidth
- UE : User Equipment
- CC : component carriers
- SSB : Synchronization Signal Block
- FR1 : Frequency Range 1 (from 450MHz to 6000MHz)
- FR2 : Frequency Range 2 (from 24250MHz to 52600MHz)

Document List

[Search on Google 15.8.0]

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications"

[2] 3GPP TS 38.201: "NR; Physical Layer – General Description"

[3] 3GPP TS 38.202: "NR; Services provided by the physical layer"

[4] 3GPP TS 38.211: "NR; Physical channels and modulation"

[5] 3GPP TS 38.212: "NR; Multiplexing and channel coding"

[6] 3GPP TS 38.213: "NR; Physical layer procedures for control"

[6] 3GPP TS 38.214: "NR; Physical layer procedures for data"

[7] 3GPP TS 38.215: "NR; Physical layer measurements"

[8-1] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone"

[8-2] 3GPP TS 38.101-2: "NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone"

[8-3] 3GPP TS 38.101-3: "NR; User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios"

[9] 3GPP TS 38.104: "NR; Base Station (BS) radio transmission and reception"

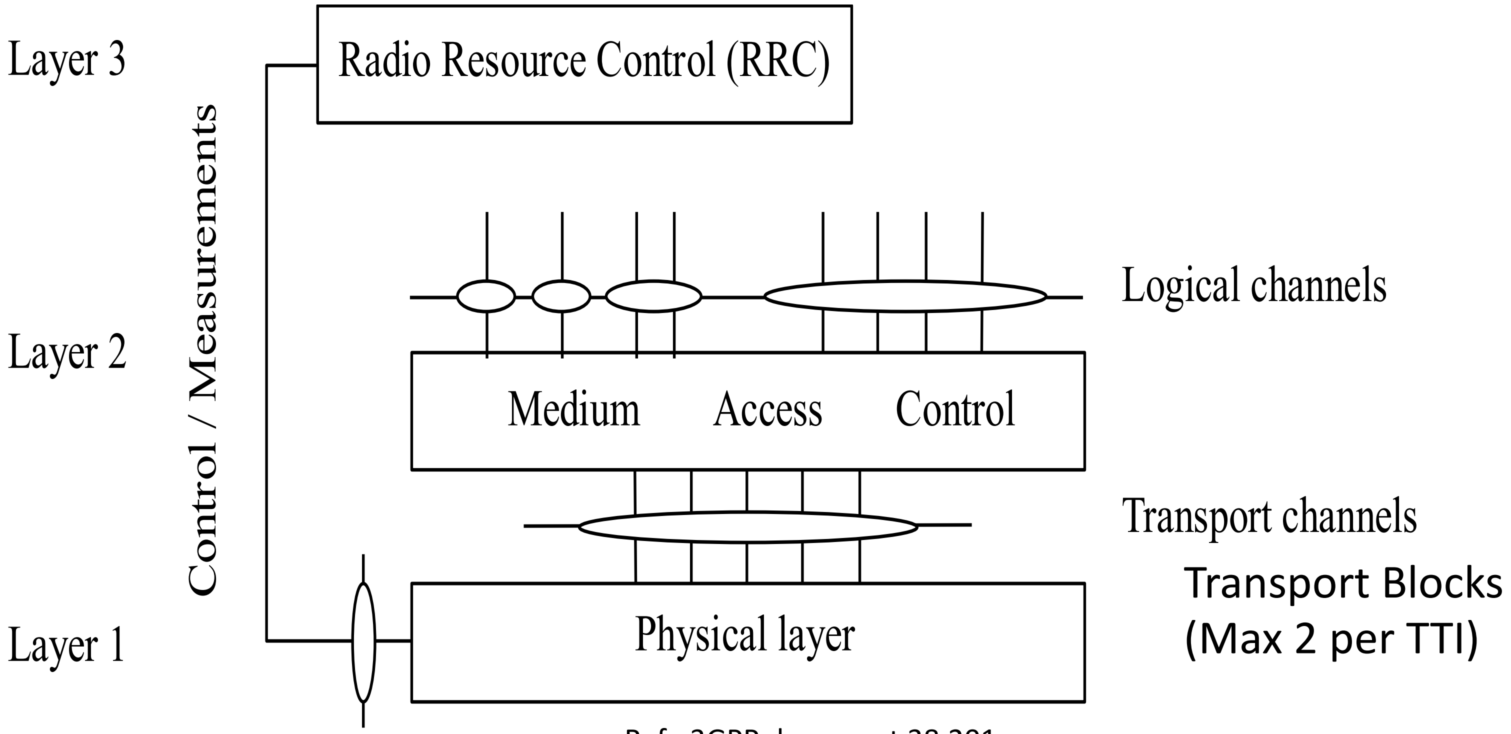
[10] 3GPP TS 38.133: "NR; Requirements for support of radio resource management"

[11] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification"

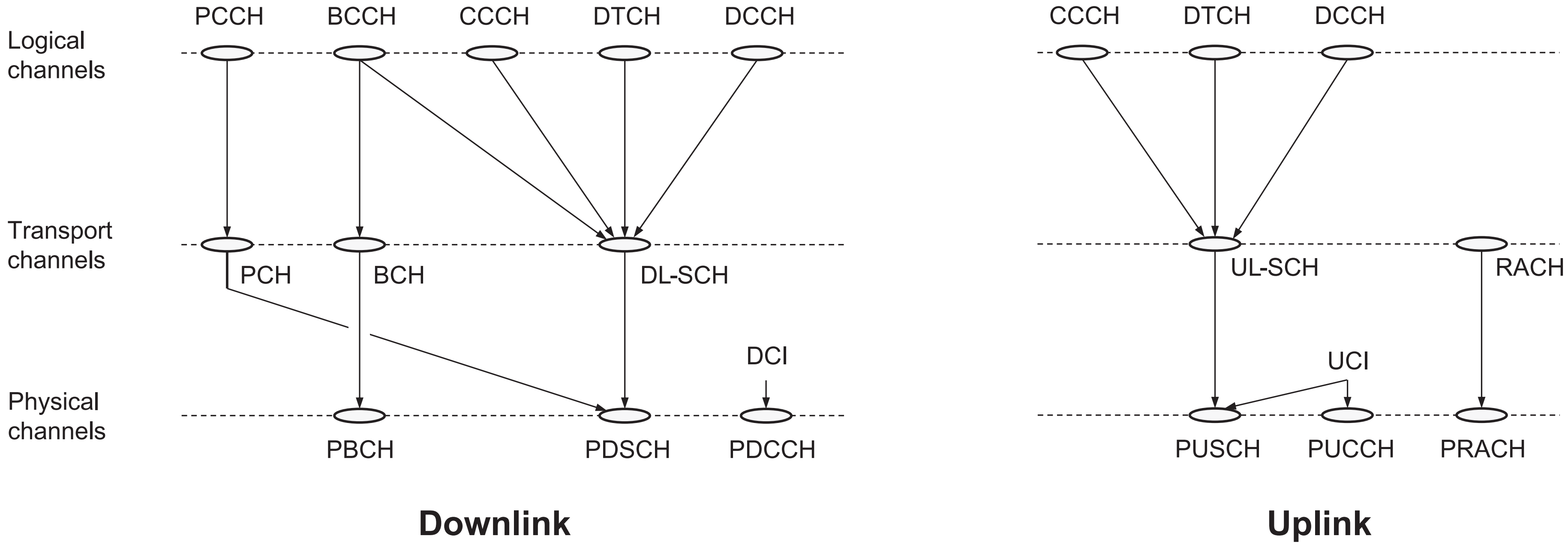
[12] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification"

[13] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures"

Layer 1



Ref: 3GPP document 38.201



Logical channels
Transport channels
Physical channels
PCCH
BCCH
CCCH
DTCH
DCCH
PCH
BCH
DL-SCH
DCI
PBCH
PDSCH
PDCCH
Downlink
CCCH
DTCH
DCCH
UL-SCH
RACH
UCI
PUSCH
PUCCH
PRACH
Uplink

Channels [Come from the MAC layer as transport blocks]

Downlink

- the Physical Downlink Shared Channel (PDSCH),
  - Used for data transmission
- the Physical Downlink Control Channel (PDCCH),
  - Used for downlink control information
- the Physical Broadcast Channel (PBCH),
  - Carries system information

Uplink

- the Physical Random Access Channel (PRACH),
  - Initial access
- the Physical Uplink Shared Channel (PUSCH),
  - Uplink data channel
- and the Physical Uplink Control Channel (PUCCH).
  - Uplink control channel

Signals [Generated in the Phy layer]

-Reference signals

- Primary and Secondary sync signals

Modulation Schemes and Coding

Downlink

- QPSK
- 16 QAM
- 64 QAM
- 256 QAM

Uplink [OFDM]

- QPSK
- 16 QAM
- 64 QAM
- 256 QAM

Uplink [DFT-s-OFDM]

- Pi/2 BPSK
- QPSK
- 16 QAM
- 64 QAM
- 256 QAM

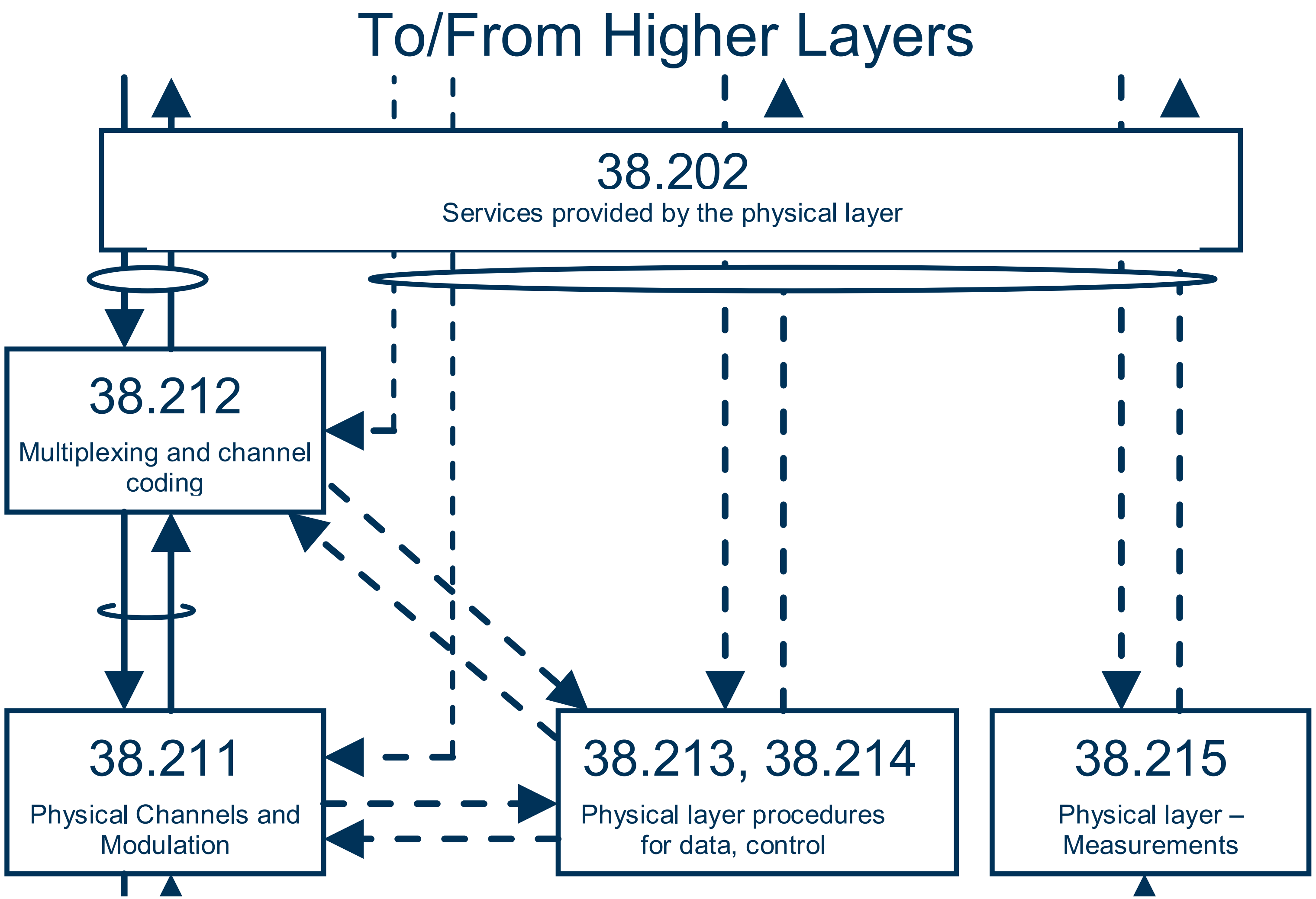
Coding

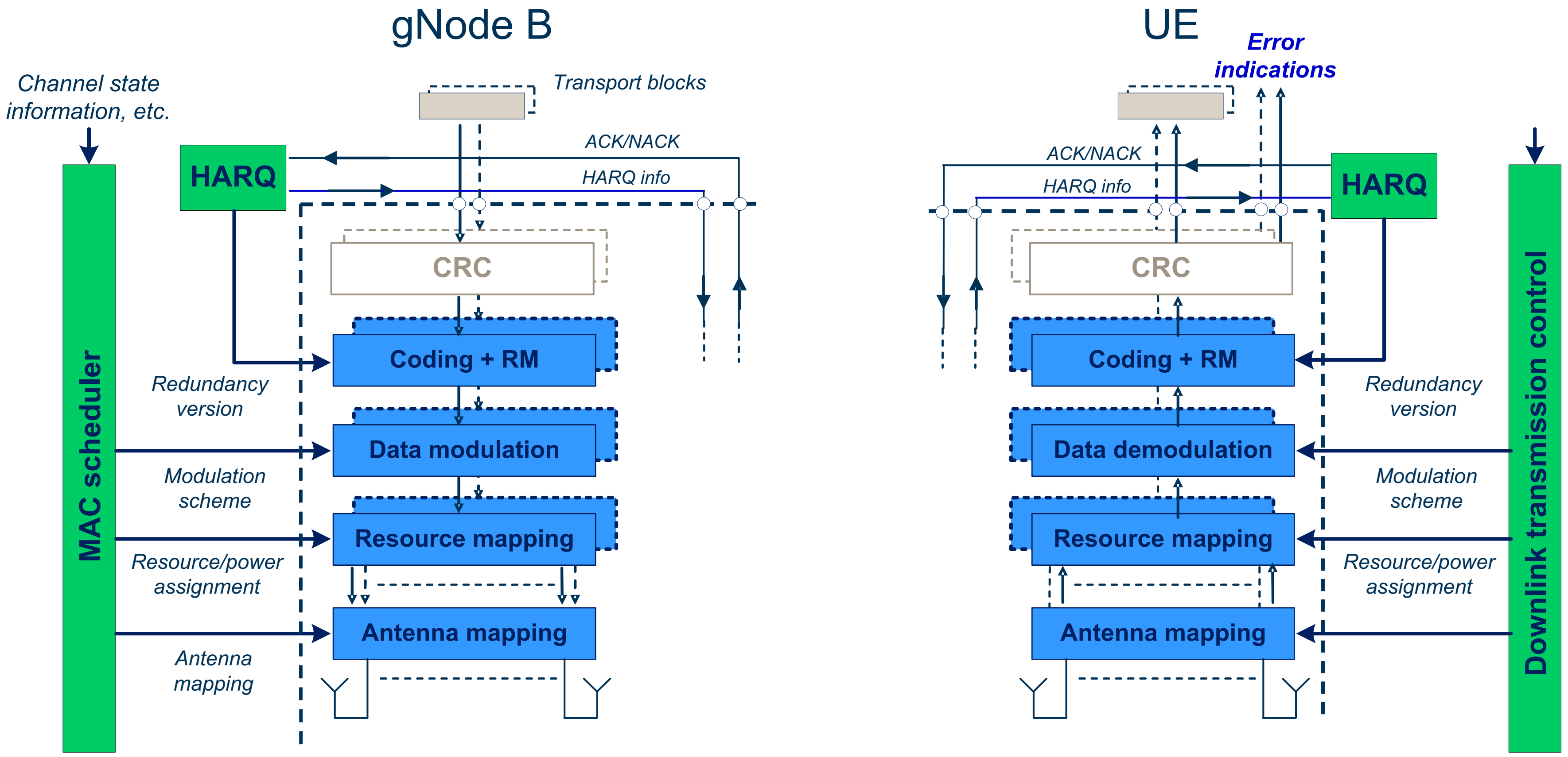
- Data: LDPC
- Control: Polar coding

Physical layer procedures

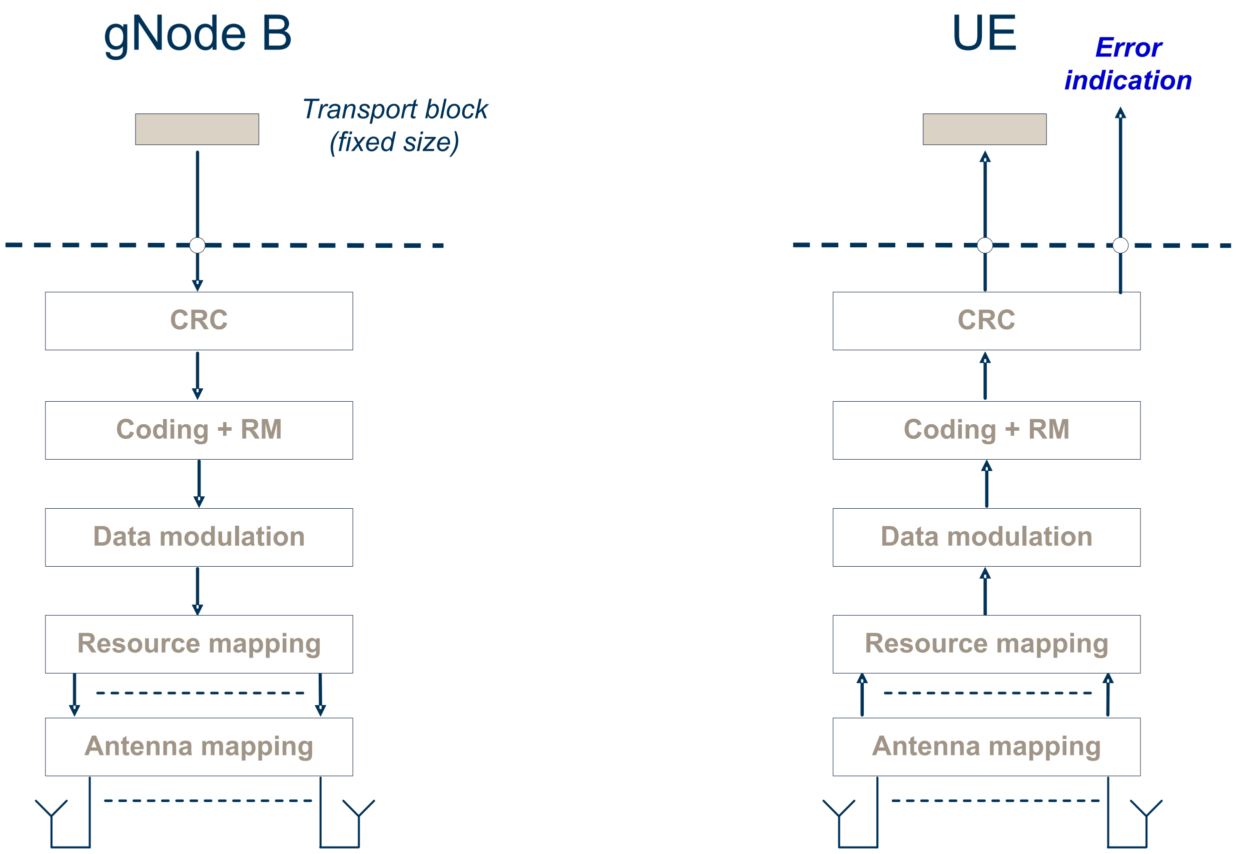
Physical layer procedures

- Cell search
- Power control
- Uplink synchronisation and Uplink timing control
- Random access related procedures
- HARQ related procedures
- Beam management and CSI related procedures


To/From Higher Layers
38.202
Services provided by the physical layer
38.212
Multiplexing and channel coding
38.211
Physical Channels and Modulation
38.213, 38.214
Physical layer procedures for data, control
38.215
Physical layer – Measurements



Physical-layer model for DL-SCH transmission



Physical-layer model for BCH transmission

Frame Structure

Sampling Rates

- Basic unit of time is $T_c = 1/(\Delta f_{max} \cdot N_f)$ where $\Delta f_{max} = 480 \cdot 10^3$ Hz and $N_f = 4096$
  - Tc=1/(480e3 x 4096)
  - Corresponds to a BW (or a sampling rate) of 1.96608 GHz
  - Ts=1/(15e3 x 2048) (Sampling time of LTE corresponding to 30.72 MHz.)
  - K = Ts/Tc = 64
  - Lower BW corresponds to multiples of Tc.

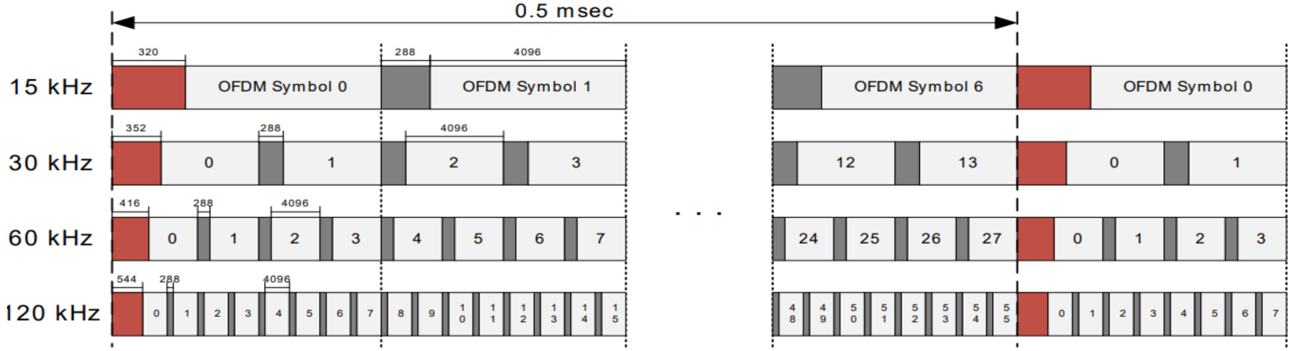
Sub-Carrier Spacing [Numerology]

- Multiple Sub-Carrier spacings are allowed in 5G NR
- LTE allowed only 15KHz SCS.
- To ensure that the timing synchronization holds at subframe boundaries, the SCS is designed to ensure that an integral multiple of slots in a higher SCS fits in the same time duration as a lower SCS slot.
- As the SCS increases, the duration of a symbol decreases according to $T_u = 1/\Delta f$

μ	$\Delta f = 2^{\mu} * 15_{[kHz]}$	CP	Frequency
0	15	Normal	FR1
1	30	Normal	FR1
2	60	Normal / Extended	FR1/FR2
3	120	Normal	FR2
4	240	Normal	FR2

```
BWP ::=                                    SEQUENCE {
    locationAndBandwidth                       INTEGER (0..37949),
    subcarrierSpacing                          SubcarrierSpacing,
    cyclicPrefix                               ENUMERATED { extended }
}
```

Frame Structure.



- Each frame is of duration $T_f = (\Delta f_{max} N_f / 100) \cdot T_c = 10\,\text{ms}$
- Frame is identified by SFN
- Each frame is divided into two half-frames
  - First half: 0 – 4 sub frames
  - Second half: 5 – 9 sub frames
- In a subframe slots are numbered as $n_s^\mu \in \{0, \ldots, N_{slot}^{subframe,\mu} - 1\}$
- In a frame slots are numbered as $n_{s,f}^\mu \in \{0, \ldots, N_{slot}^{frame,\mu} - 1\}$
- The number of OFDM symbols in a slot is denoted as N_{symb}^{slot}
  - Equals 14
- Number of slots in sub frame
  - Depends on SCS

Number of OFDM symbols per slot, slots per frame, and slots per subframe for normal cyclic prefix.

μ	N_{symb}^{slot}	$N_{slot}^{frame,\mu}$	$N_{slot}^{subframe,\mu}$
0	14	10	1
1	14	20	2
2	14	40	4
3	14	80	8
4	14	160	16

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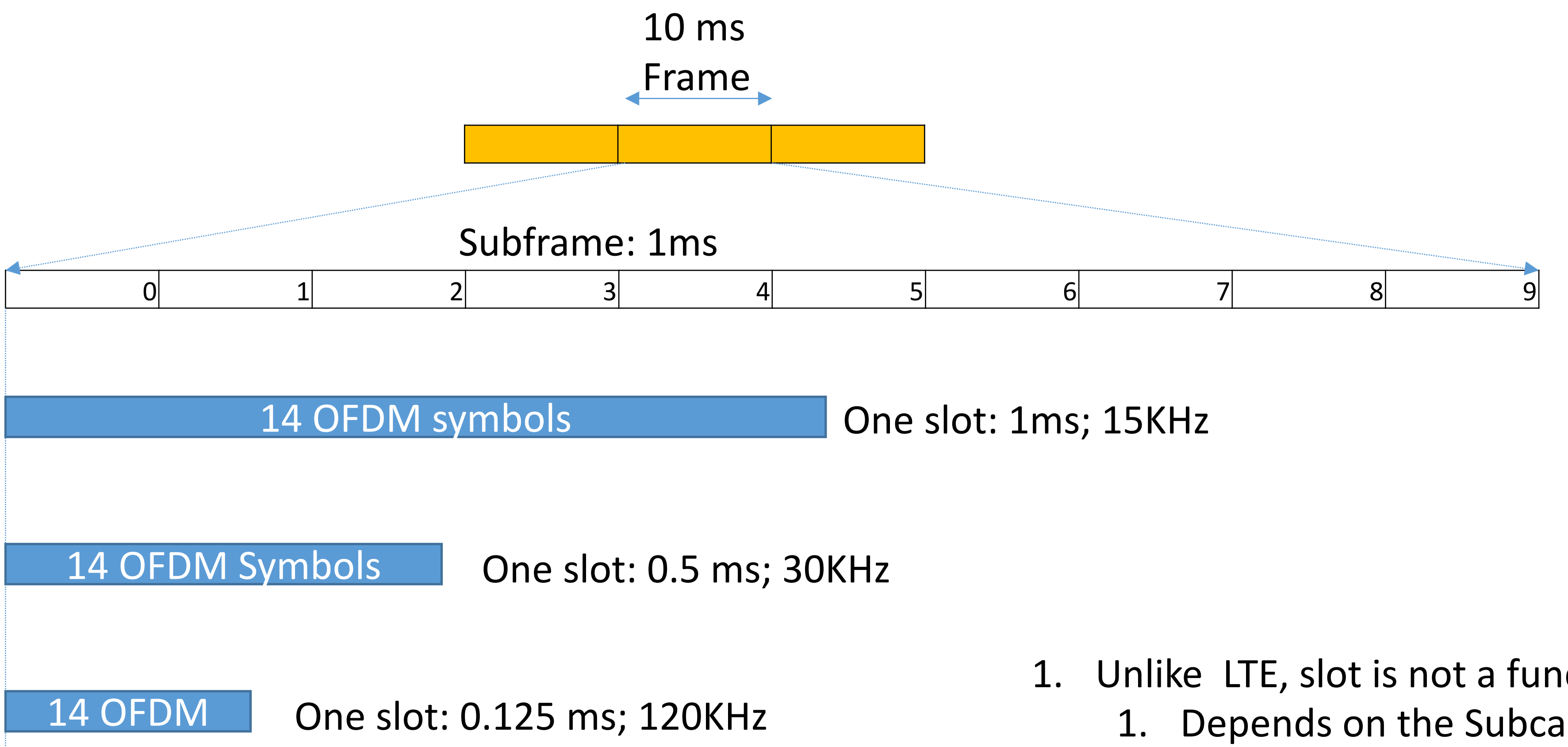
Time-Frequency Grid in 5G NR

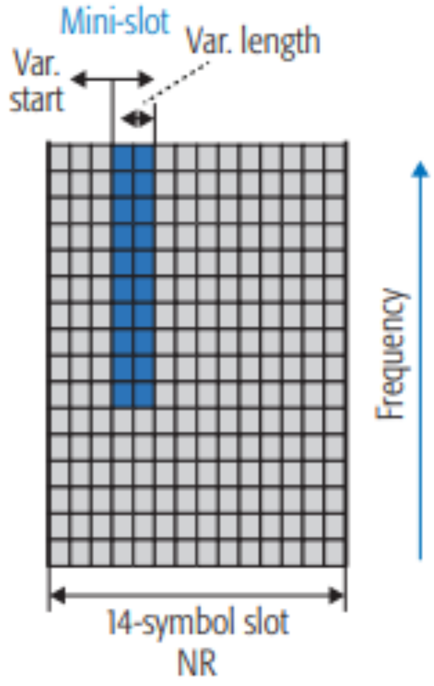


1. Unlike LTE, slot is not a fundamental
    1. Depends on the Subcarrier spacing
    2. # of slots in a sub frame depend on the SCS

Slots

- Slots are defined such that data contained in it is decodable without any data from other slots.
- Subframes are split into slots and each slot has 14 OFDM symbols.
  - A slot can contain 7 or 14 OFDM symbols for SCS <=60kHz, while a slot always has 14 OFDM symbols for SCS >= 120kHz
- Release 15/16 supports slots with 14 symbols.

- Mini slots are also defined to be used for low latency applications and for forward compatibility.
  - They can start at any time and can be as small as one OFDM symbol.
  - They are the smallest scheduling unit
  - They can have 2,4 or 7 symbols



Not implemented in Rel 15

Ports

- Will describe in detail once we start MIMO in a few classes.

- For now, assume port is equal to an antenna
    - Each port will have its own reference signals

Resource Grid (Part1)

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- Number of sub carriers: $N^{\text{size},\mu}_{\text{grid},x} N^{\text{RB}}_{\text{sc}}$
  - x: UL/DL

Given by the higher layer parameter carrierBandwidth

- Number of OFDM symbols : $N^{\text{subframe},\mu}_{\text{symb}}$

- Starting Common Resource Block : $N^{\text{start},\mu}_{\text{grid}}$
  - Indicated by higher layers sig: *offsetToCarrier*

```
SCS-SpecificCarrier ::=                  SEQUENCE {
    offsetToCarrier                          INTEGER (0..2199),
    subcarrierSpacing                        SubcarrierSpacing,
    carrierBandwidth                         INTEGER (1..maxNrofPhysicalResourceBlocks),
    ...,
    [[
    txDirectCurrentLocation              INTEGER (0..4095)
    ]]
}
```

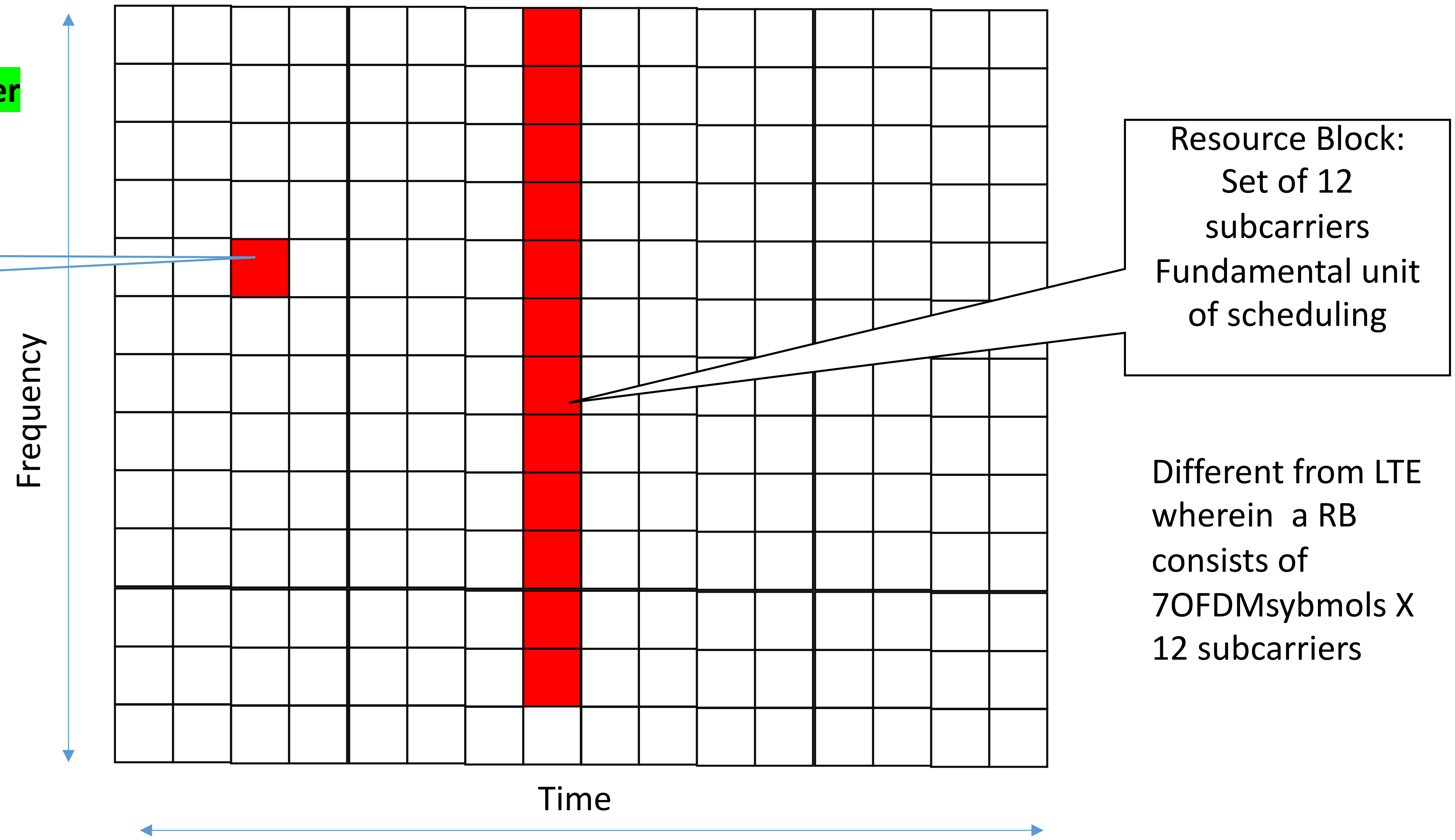
```
maxNrofPhysicalResourceBlocks              INTEGER ::= 275      -- Maximum number of PRBs
```

SIB1 →ServingCellConfigCommonSIB →DownlinkConfigCommonSIB →FrequencyinfoDL-SIB/ FrequencyinfoUL-SIB →SCS-SpecificCarrier

Resource Element and Blocks

N_{sc}^{RB} **# of RB per subcarrier**

Resource Element



$(k,l)_{p,u}$: $a_{k,l}^{(p,\mu)}$

K: indicates frequency domain

l: indicates OFDM symbols

Different from LTE wherein a RB consists of 7OFDMsybmols X 12 subcarriers

Resource Blocks and Maximum CBW

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38.101-1

38.101-2

- A resource block is a contiguous set of 12 subcarriers.
- Each numerology has a limit on the number of physical resource blocks it can support. (38.101-1 and 38.101-2)
- LTE uses OFDM with a spectral efficiency of 90%, i.e, an LTE band of 20MHz uses only 18MHz and the remaining 2MHz are used as guard bands on either side of the utilized bandwidth.
  - Eg: 100 MHz➔ No PRB = 273 ➔ used BW = 273*30*12= 98.2 MHz ➔ 98.2% efficient
- NR attempts at 98% spectral efficiency using CP-OFDM.

Transmission bandwidth configuration N_{RB} for FR1 [38.101-1]

SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	80 MHz	90 MHz	100 MHz
	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}
15	25	52	79	106	133	160	216	270	N/A	N/A	N/A	N/A
30	11	24	38	51	65	78	106	133	162	217	245	273
60	N/A	11	18	24	31	38	51	65	79	107	121	135

Transmission bandwidth configuration N_{RB} for FR2

SCS (kHz)	50 MHz	100 MHz	200 MHz	400 MHz
	N_{RB}	N_{RB}	N_{RB}	N_{RB}
60	66	132	264	N.A
120	32	66	132	264

Source: 38.101-1 and 38.101-2

Primary cell, Secondary cell and Serving cell

- Primary cell (Pcell): The MCG cell, operating on the primary frequency, in which the UE either performs the initial connection establishment procedure or initiates the connection re-establishment procedure.
- Secondary cell: For a UE configured with CA, a cell providing additional radio resources on top of Special Cell
- Serving cell: For a UE in RRC_CONNECTED not configured with CA/DC there is only one serving cell comprising of the primary cell. For a UE in RRC_CONNECTED configured with CA/ DC the term 'serving cells' is used to denote the set of cells comprising of the Special Cell(s) and all secondary cells.

Coordinate system

- Multiple numerologies are present in NR
- Channels (theoretically) can have different SCS
  - PDSCH, PBCH..
- How do we specify frequency locations of all these channels to the UE?
- We require a common reference point
  - Point A

Point A (Common reference point) and offset to carrier

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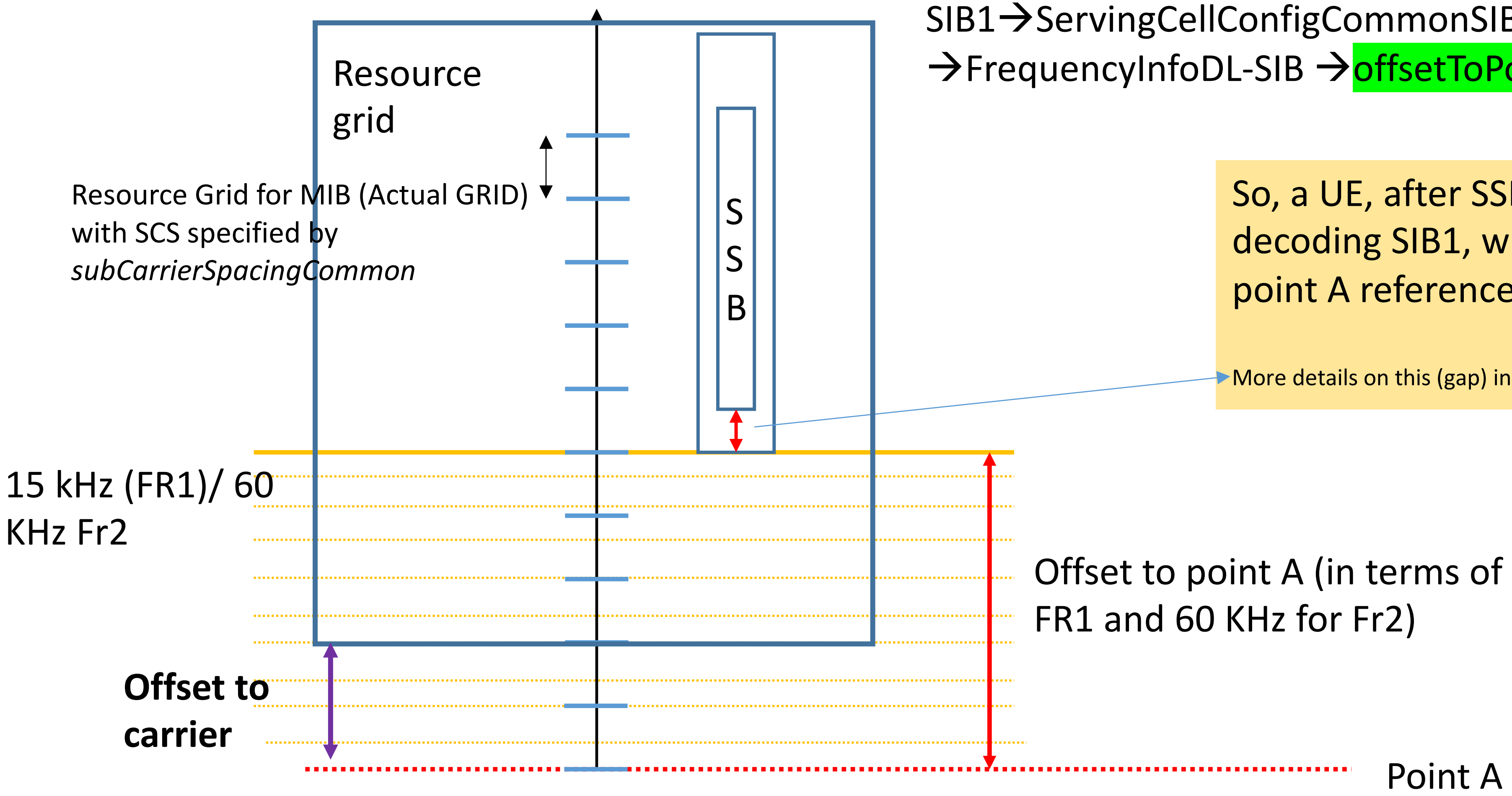
```
FrequencyInfoDL-SIB ::=              SEQUENCE {
    frequencyBandList                    MultiFrequencyBandListNR-SIB,
    offsetToPointA                       INTEGER (0..2199),
    scs-SpecificCarrierList              SEQUENCE (SIZE (1..maxSCSs)) OF SCS-SpecificCarrier
}
```

SIB1→ServingCellConfigCommonSIB→DownlinkConfigCommonSIB →FrequencyInfoDL-SIB →offsetToPointA



So, a UE, after SSB synchronization and decoding SIB1, will be able to identify the point A reference **

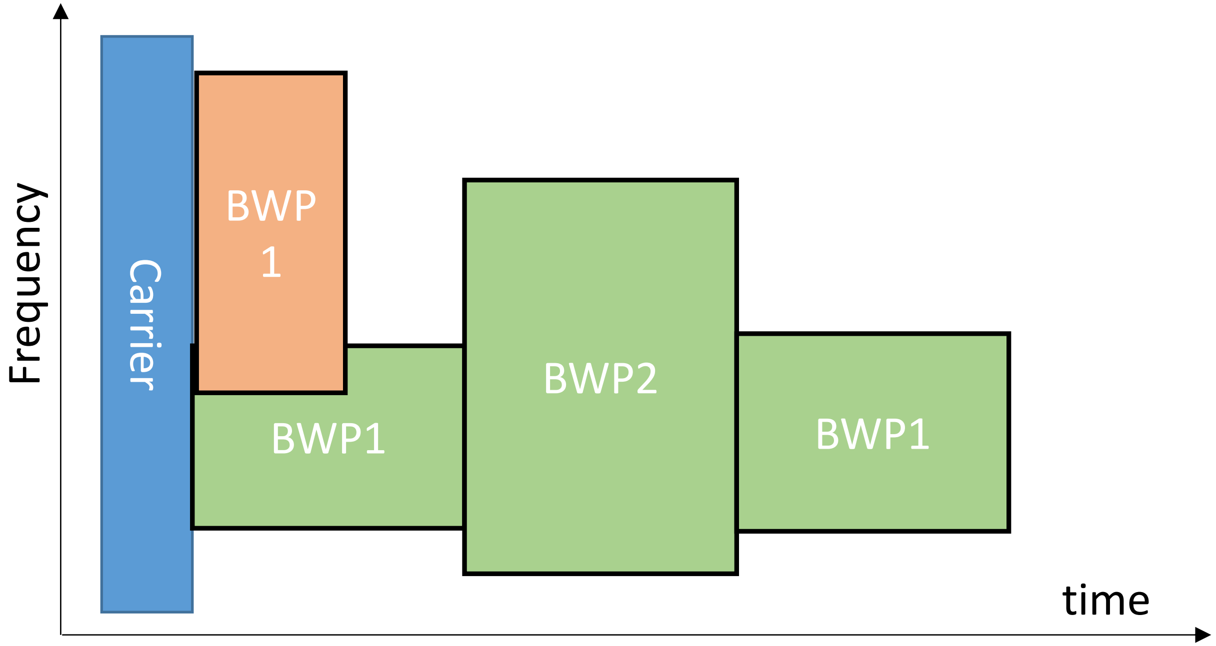
More details on this (gap) in the SSB sync lecture

**This is for Pcell. For other cells, absoluteFrequencyPointA is used and is specified in terms of ARFCN

Band Width Part (BWP) introduction

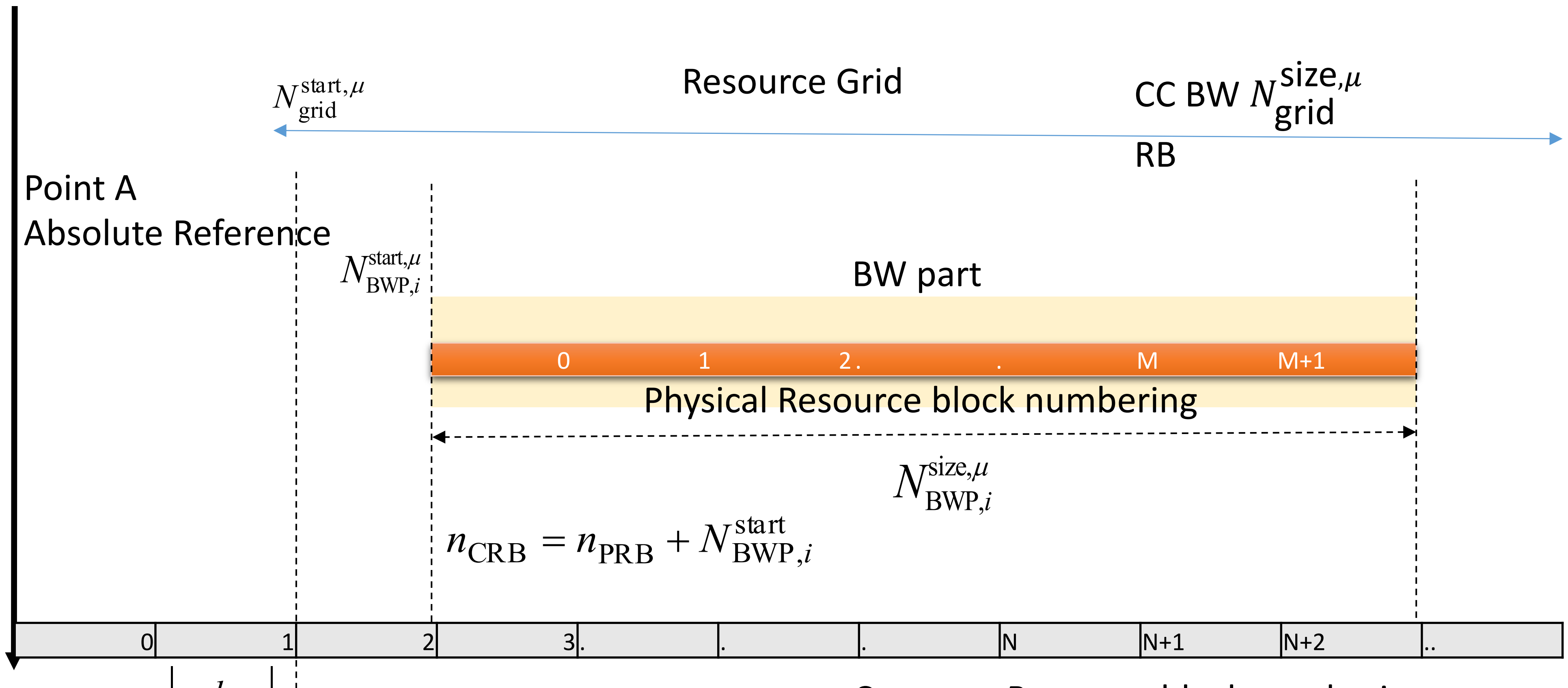
- NR supports a wide BW.
  - A UE might not require high BW at all times
  - A UE might not be able to process high bandwidth
- To reduce the power consumption from RF and baseband computation, each UE is assigned a BWP.
  - They have a lower BW, outside which the UE is not required to transmit or receive signals.
- The BWPs assigned to a UE can overlap in frequency and can be of different numerologies.

- DL/UL
  - UE can have 4 BWP
  - Only one active BWP at a time



**More about BWP after SSB and MIB classes

Common Resource Blocks and Physical Resource Blocks



$n_{\text{CRB}}^{\mu} = \left\lfloor \frac{k}{N_{\text{sc}}^{\text{RB}}} \right\rfloor$, where k is the resource element

FFT Size and Sampling

- Example 1: 30 KHz SCS and 100 MHZ BW
  - From the above table we require 273 RB = 273*12 = 3276 subcarriers (used)
  - Therefore, we choose 4096 size FFT/IFFT
  - Sampling time= 1/(4096*30e3) = 16*Tc (recall 64Tc corresponds to 30.72 MSps (LTE))
  - Sampling frequency = 4*30.72 = 122.88 MSps
- Example 2: 30 KHz SCS and 50 MHZ BW
  - From the above table we require 133 RB = 133*12 = 1596 subcarriers (used)
  - Therefore, we choose 2048 size FFT/IFFT
  - Sampling time= 1/(2048*30e3) = 32*Tc
  - Sampling frequency = 2*30.72 = 61.44 MSps
- Example 3: 120 KHz SCS and 400 MHZ BW
  - From the above table we require 264 RB = 264*12 = 3168 subcarriers (used)
  - Therefore, we choose FFT/IFFT Size = 4096
  - Sampling time = 1/(4096*120e3) = 4*Tc
  - Sampling frequency = 16*30.72 = 491.52 MSps

OFDM Signal/CP duration

For OFDM symbol $l \in \left\{0,1,\ldots,N_{\text{slot}}^{\text{subframe},\mu} N_{\text{symb}}^{\text{slot}} - 1\right\}$

$$N_{\text{u}}^{\mu} = 2048\kappa \cdot 2^{-\mu}$$

$$N_{\text{CP},l}^{\mu} = \begin{cases} 512\kappa \cdot 2^{-\mu} & \text{extended cyclic prefix} \\ 144\kappa \cdot 2^{-\mu} + 16\kappa & \text{normal cyclic prefix, } l = 0 \text{ or } l = 7 \cdot 2^{\mu} \\ 144\kappa \cdot 2^{-\mu} & \text{normal cyclic prefix, } l \neq 0 \text{ and } l \neq 7 \cdot 2^{\mu} \end{cases}$$

Cyclic Prefix

$$N_u^\mu = 2048\kappa \cdot 2^{-\mu}$$

$$N_{CP,l}^\mu = \begin{cases} 512\kappa \cdot 2^{-\mu} & \text{extended cyclic prefix} \\ 144\kappa \cdot 2^{-\mu} + 16\kappa & \text{normal cyclic prefix, } l = 0 \text{ or } l = 7 \cdot 2^\mu \\ 144\kappa \cdot 2^{-\mu} & \text{normal cyclic prefix, } l \neq 0 \text{ and } l \neq 7 \cdot 2^\mu \end{cases}$$

- Cyclic Prefix length (time) = $Tc*N_{CP,l}^u$
- Extra CP length for 0,7 OFDM symbols (for 15KHz)
- Extra CP length for 0,14 OFDM symbols (for 30KHz)
- Extra CP length for 0, 56 OFDM symbols (for 120KHz)

μ	0	1	2	3	4
SCS(khz)	15	30	60	120	240
T_u(μs)	66.67	33.33	16.67	8.33	4.17
CP(μs)	4.69	2.34	1.17	0.57	0.29

Effective Duration of the OFDM symbol (with CP)

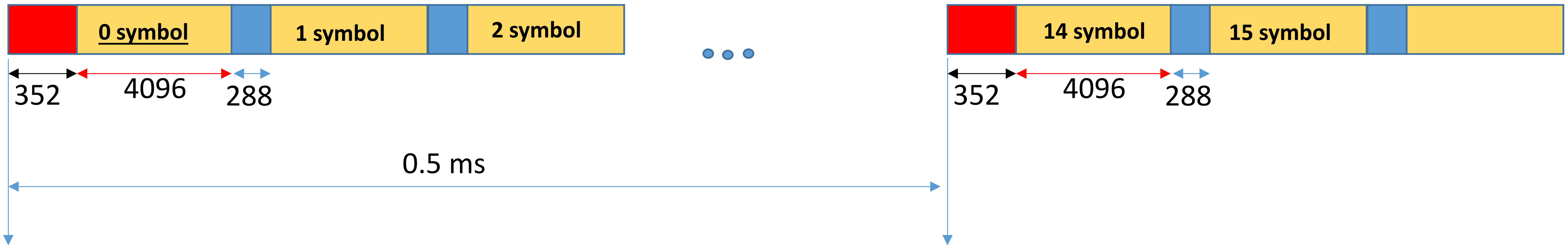
- Example 1: 30 KHz SCS and 100 MHZ BW
  - Sampling time = 16*Tc (See previous page)
  - Total time (excluding CP) = 16*Tc*4096 = 16*4096*1/(480e3 x 4096) = 33.33 us
  - CP time = 144/2*64*Tc = 2.34us (other than 0 and 14^{th} symbol…)
- Example 2: 30 KHz SCS and 50 MHZ BW
  - Sampling time = 32*Tc
  - Total time (excluding CP) = 32*Tc*2048 = 33.33 us
  - CP time = 144/2*64*Tc = 2.34us (other than 0 and 14^{th} symbol…)
- Example 3: 120 KHz SCS and 400 MHZ BW
  - Sampling time = 4*Tc
  - Total time(excluding CP) = 4*Tc*4096 =8.3us
  - CP time = 144/8*64*Tc = 0.58us (other than 0 and 56^{th} symbol…)

Summary of Frame Structure

30 KHz SCS and 100 MHZ BW

- Sampling rate: 122.88 MSPS (Sampling time 16Tc)
- FFT Size: 4096
- Useful subcarriers: 3276 (Corresponds to 98.280MHz)
- 14 symbols/slot
- Slot Duration = 0.5 ms = (352 + 288*13+4096*14)*16Tc
- 2 slots/subframe

Sampling time



CP Length (samples) =

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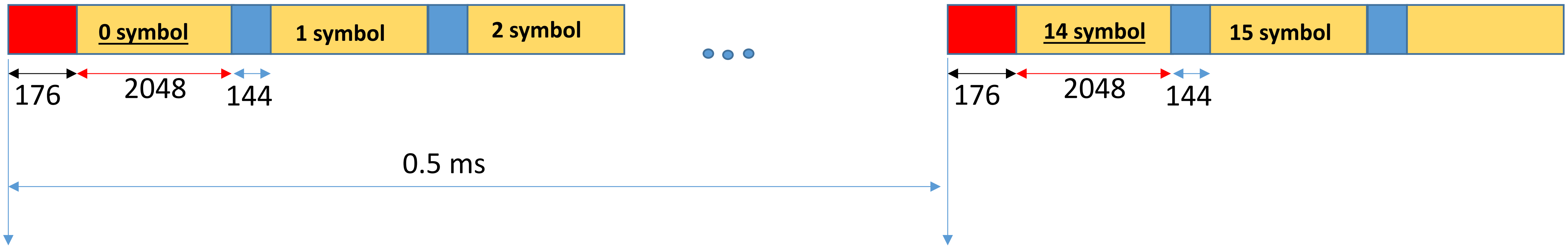
Summary of Frame Structure

30 KHz SCS and 50 MHZ BW

- Sampling rate: 61.44 MSPS (Sampling time 32Tc)
- FFT Size: 2048
- Useful Subcarriers: 1596 (Corresponds to 47.88 MHz)
- 14 symbols/slot
- Slot Duration = 0.5 ms = (176 + 144*13+2048*14)*32Tc
- 2 slots/subframe

Sampling time

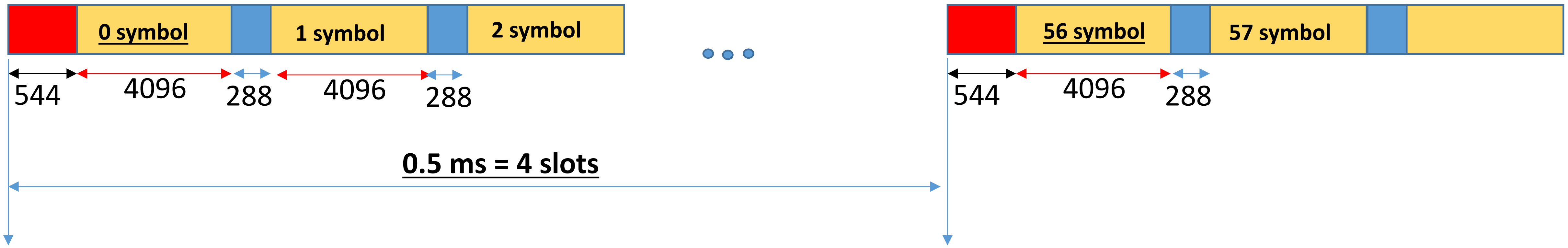


Summary of Frame Structure

120 KHz SCS and 400 MHZ BW

- Sampling rate: 491.52 MSPS (Sampling time 4Tc)
- FFT Size: 4096
- Useful Subcarriers: 3168 (corresponds to 380.16 MHz)
- 14 symbols/slot
- Slot Duration = 0.125 ms = (544 + 288*13+4096*14)*4Tc [CHECK THIS. Not exactly 0.125ms]
- 8 slots/subframe

Sampling time



OFDM signal generation

$$s_l^{(p,\mu)}(t) = \sum_{k=0}^{N_{\text{grid}}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}} - 1} a_{k,l}^{(p,\mu)} \cdot e^{j2\pi\left(k + k_0^\mu - N_{\text{grid},x}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}}/2\right)\Delta f\left(t - N_{\text{CP},l}^\mu T_c - t_{\text{start},l}^\mu\right)}$$

$$k_0^\mu = \left(N_{\text{grid},x}^{\text{start},\mu} + N_{\text{grid},x}^{\text{size},\mu}/2\right) N_{\text{sc}}^{\text{RB}} - \left(N_{\text{grid},x}^{\text{start},\mu_0} + N_{\text{grid},x}^{\text{size},\mu_0}/2\right) N_{\text{sc}}^{\text{RB}} 2^{\mu_0 - \mu}$$

- μ_0 is the largest μ value among the subcarrier spacing configurations by the higher-layer parameter *scs-SpecificCarrierList*.

The starting position of OFDM symbol l for subcarrier spacing configuration μ in a subframe is given by

$$t_{\text{start},l}^\mu = \begin{cases} 0 & l = 0 \\ t_{\text{start},l-1}^\mu + \left(N_u^\mu + N_{\text{CP},l-1}^\mu\right) \cdot T_c & \text{otherwise} \end{cases}$$

SIB1→ServingCellConfigCommonSIB→ DownlinkConfigCommonSIB →*FrequencyInfoDL-SIB*→scs-SpecificCarrierList

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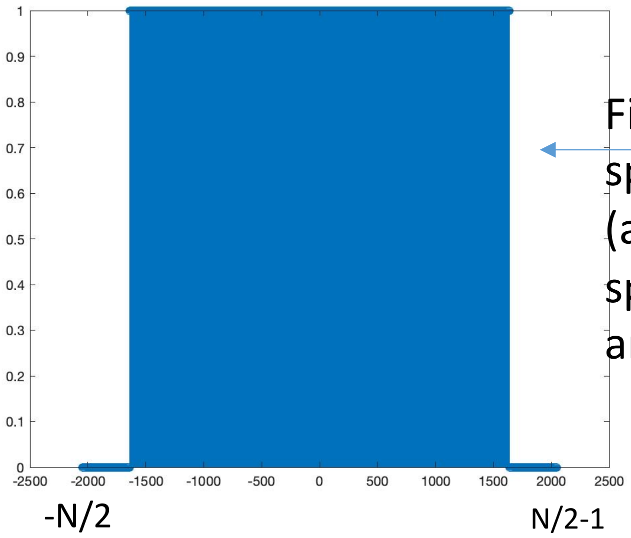
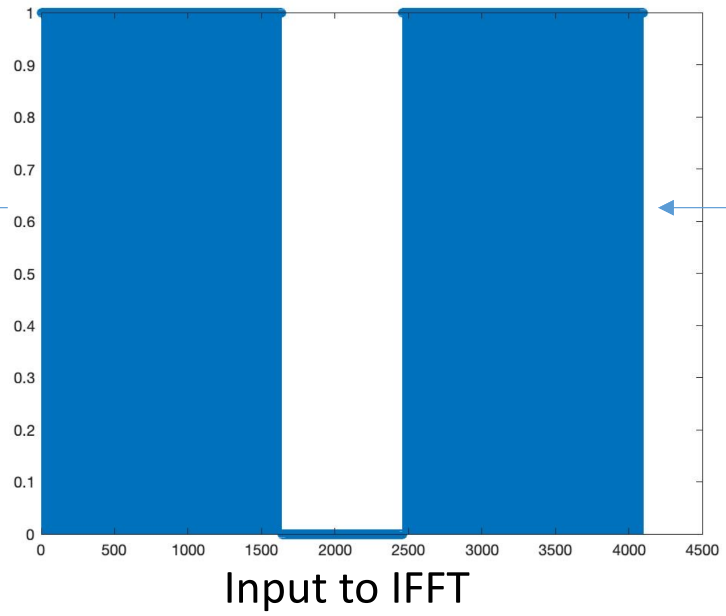
Generation (cont....)

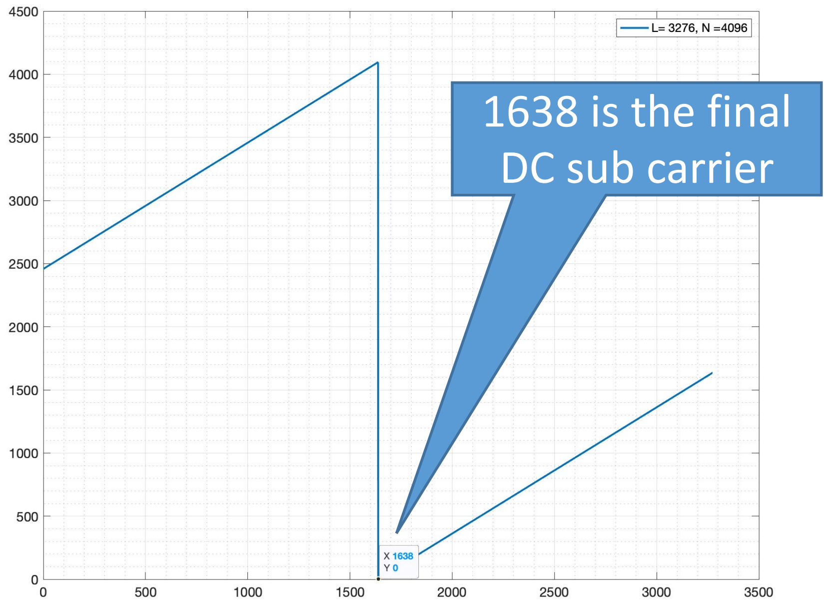
- For a given SCS, $K_0^u = 0$
- After a little analysis, the mapping boils down to k → $\underline{K}$= mod((k-L/2),N), k=0,1,2,..,L-1
  - k is the sub-carrier index in the resource grid.
  - $\underline{K}$ is the index for the input to the N point IFFT.
  - L is the resource grid size (in frequency domain, i.e., no of RE) and is always even (since grid size is specified in PRB and is multiple of 12)
  - N is the FFT size.

#RE/2 is the final DC sub-carrier



Final spectrum (as in spectrum analyzer)





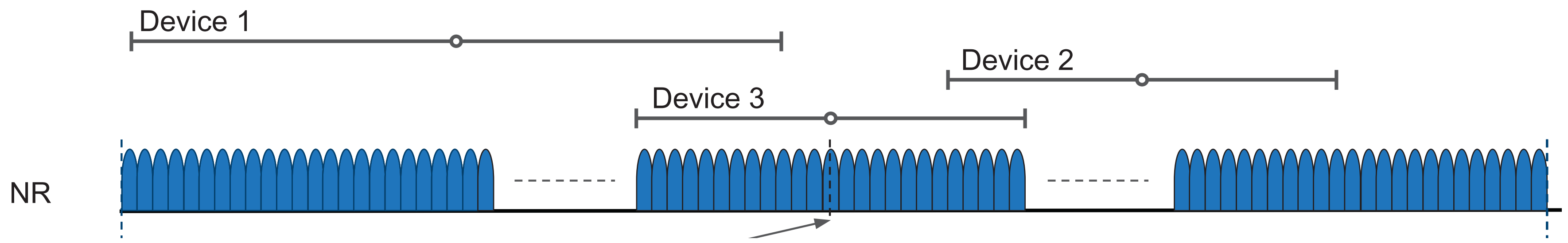
Effective Mapping (contd…)

```
% Matlab code for illustrating the movement of sub-carries in the final output

N=4096; % FFT Size

N_RB =273; % No RB
N_SC = N_RB*12; % No of populated subcarriers
FFT_in = zeros(1, N);

index_RE= mod((1:N_SC)-N_SC/2, N)+1; % +1 since Matlab indexing starts from 1

X= 1:1:N_SC; % Dummy data in the subcarriers. We can identify the sub-carrier by the data it carries

FFT_in(index_RE)= X; % Input to the IFFT

out_frame_time = sqrt(N)*ifft(FFT_in); % IFFT

% Plotting the frequency domain by FFT and FFT shift.

stem((-N/2):1:(N/2-1),abs(1/sqrt(N)*fftshift(fft(out_frame_time))))
```

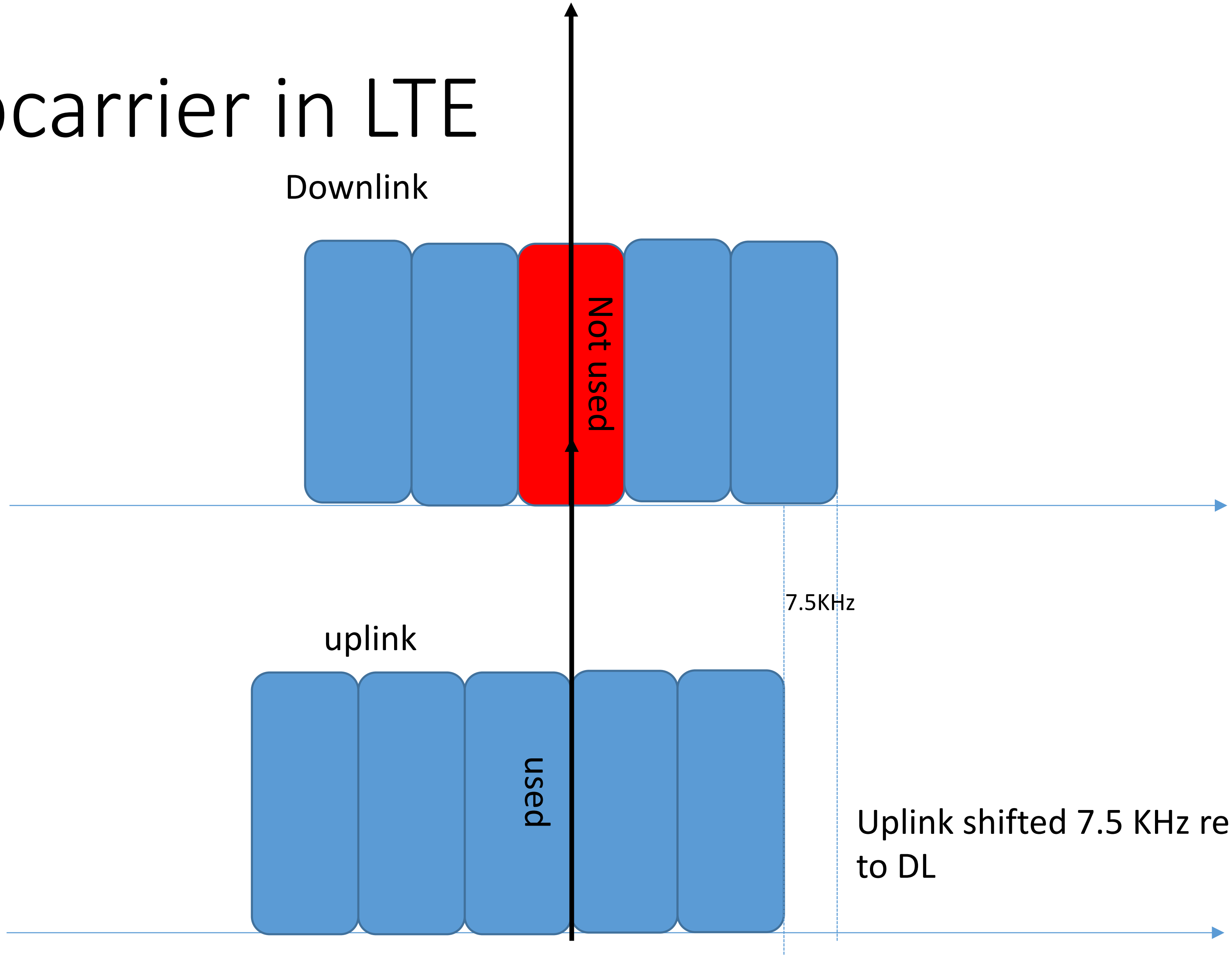
$k \rightarrow \underline{K}= \mathrm{mod}((k-L/2),N)$

DC subcarrier in 5GNR

- LTE had a BW of 20 MHZ and every UE supported 20 MHz
- In 5GNR, the BW can be as large as 400 MHz and not all UE can support it
- In 5G NR the UE need not support the entire Carrier BW. In fact it can occupy any region the supported carrier
- In LTE DC sub carrier was nulled (common)
- In 5G NR the DC subcarrier has information (no common DC)

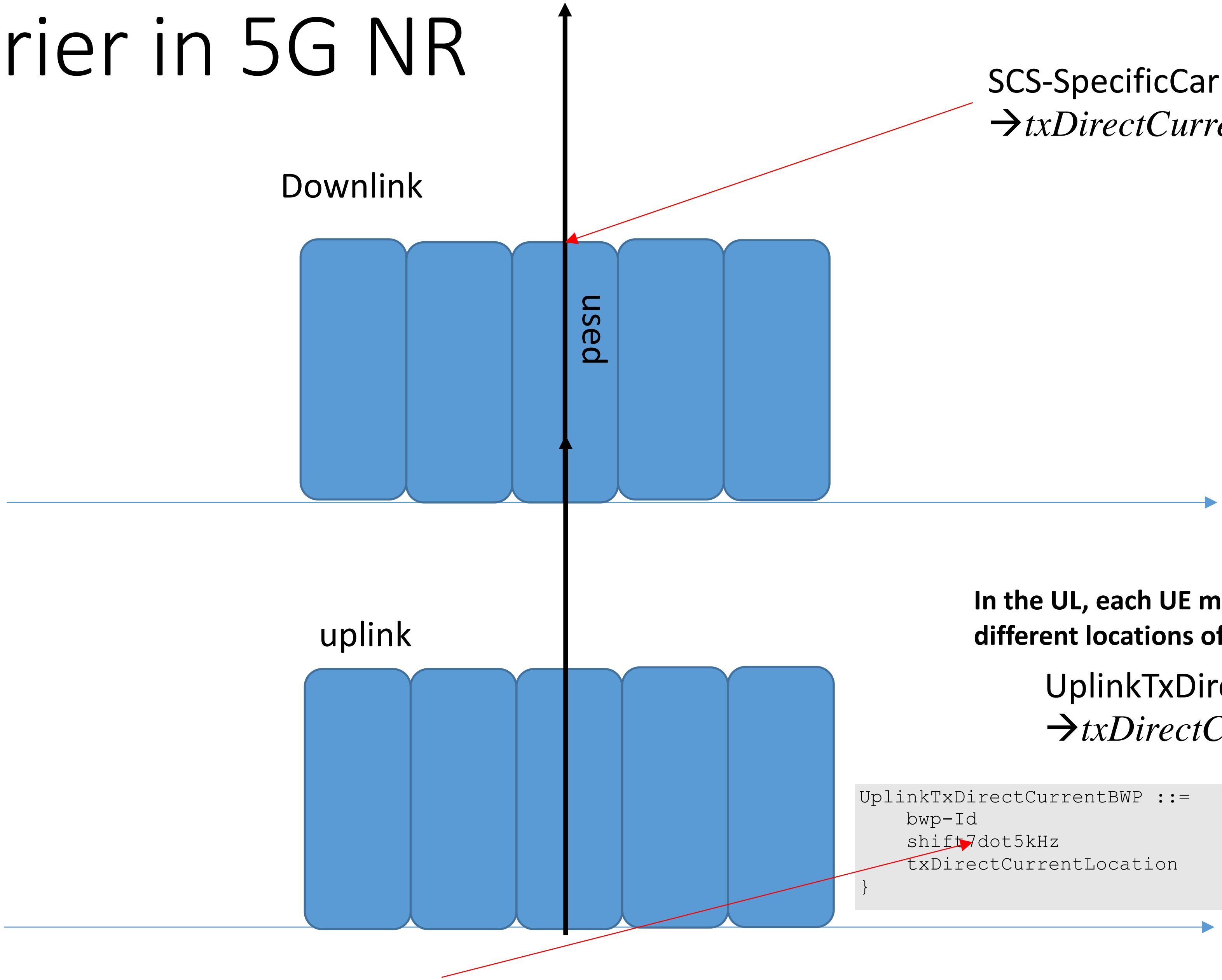


DC subcarrier in LTE



Uplink shifted 7.5 KHz relative to DL

DC subcarrier in 5G NR



SCS-SpecificCarrier
→*txDirectCurrentLocation*

In the UL, each UE might have its DC located in different locations of the carrier bandwidth

UplinkTxDirectCurrentBWP
→*txDirectCurrentLocation*

```
UplinkTxDirectCurrentBWP ::=                SEQUENCE {
    bwp-Id                                      BWP-Id,
    shift7dot5kHz                               BOOLEAN,
    txDirectCurrentLocation                     INTEGER (0..3301)
}
```

Indicates whether there is 7.5 kHz shift or not. 7.5 kHz shift is applied if the field is set to true. Otherwise 7.5 kHz shift is not applied.
Mainly for LTE alignment (to reduce interference)

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Transmission Bandwidth and guard bands

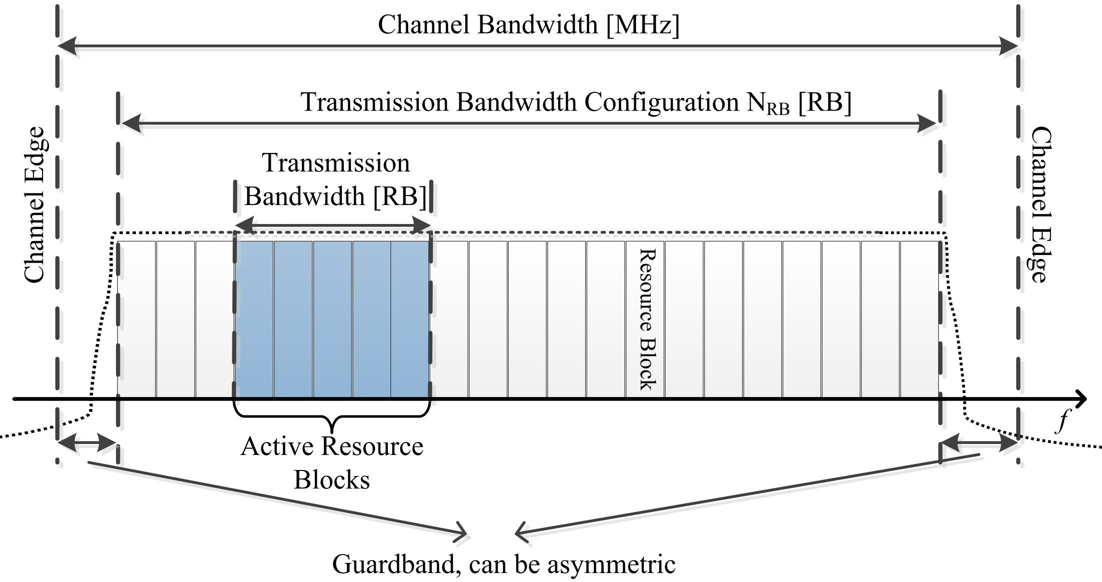

Table 5.3.2-1: *Transmission bandwidth configuration* N_{RB} for FR1

SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	70 MHz	80 MHz	90 MHz	100 MHz
	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}
15	25	52	79	106	133	160	216	270	N/A	N/A	N/A	N/A	N/A
30	11	24	38	51	65	78	106	133	162	189	217	245	273
60	N/A	11	18	24	31	38	51	65	79	93	107	121	135

Table 5.3.2-2: *Transmission bandwidth configuration* N_{RB} for FR2

SCS (kHz)	50 MHz	100 MHz	200 MHz	400 MHz
	N_{RB}	N_{RB}	N_{RB}	N_{RB}
60	66	132	264	N/A
120	32	66	132	264

Table 5.3.3-1: Minimum guardband (kHz) (FR1)

SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	70 MHz	80 MHz	90 MHz	100 MHz
15	242.5	312.5	382.5	452.5	522.5	592.5	552.5	692.5	N/A	N/A	N/A	N/A	N/A
30	505	665	645	805	785	945	905	1045	825	965	925	885	845
60	N/A	1010	990	1330	1310	1290	1610	1570	1530	1490	1450	1410	1370

Table: 5.3.3-2: Minimum guardband (kHz) (FR2)

SCS (kHz)	50 MHz	100 MHz	200 MHz	400 MHz
60	1210	2450	4930	N/A
120	1900	2420	4900	9860

The starting point of the transmission bandwidth configuration on the common resource block grid for a given channel bandwidth is indicated by an offset to "Reference point A" in the unit of the numerology.

Guard_Band =(Channel_BW – N_{RB}*12*SCS - SCS)/2

Due to channel raster

38.104

Channel bandwidth

Table 5.3.5-1: *BS channel bandwidths* and SCS per *operating band* in FR1

NR band / SCS / *BS channel bandwidth*														
NR Band	**SCS kHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**	**25 MHz**	**30 MHz**	**40 MHz**	**50 MHz**	**60 MHz**	**70 MHz**	**80 MHz**	**90 MHz**	**100 MHz**
n1	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60		Yes	Yes	Yes									
n2	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60		Yes	Yes	Yes									
n3	15	Yes	Yes	Yes	Yes	Yes	Yes							
	30		Yes	Yes	Yes	Yes	Yes							
	60		Yes	Yes	Yes	Yes	Yes							
n5	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60													
n7	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60		Yes	Yes	Yes									
n8	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60													
n12	15	Yes	Yes	Yes										
	30		Yes	Yes										
	60													
n20	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60													
n25	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60		Yes	Yes	Yes									
	60													
n77	15		Yes	Yes	Yes		Yes	Yes	Yes					
	30		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	60		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
n78	15		Yes	Yes	Yes		Yes	Yes	Yes					
	30		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	60		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
n79	15							Yes	Yes					
	30							Yes	Yes	Yes		Yes		Yes
	60							Yes	Yes	Yes		Yes		Yes
n80	15	Yes	Yes	Yes	Yes	Yes	Yes							
	30		Yes	Yes	Yes	Yes	Yes							
	60		Yes	Yes	Yes	Yes	Yes							

Table 5.3.5-2: *BS channel bandwidths* and SCS per *operating band* in FR2

NR band / SCS / *BS channel bandwidth*					
NR Band	**SCS kHz**	**50 MHz**	**100 MHz**	**200 MHz**	**400 MHz**
n257	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n258	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n260	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n261	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes

Global Raster

- Global frequency raster defines a set of RF reference frequencies : F_{ref}
  - Used to locate RF channels.
  - Defined from 0…100GHz
  - Granularity: Δf_{Global}
- RF reference frequencies are designated by an NR Absolute Radio Frequency Channel Number (NR-ARFCN)
  - Range [0…3279165]

$$F_{REF} = F_{REF\text{-}Offs} + \Delta F_{Global} (N_{REF} - N_{REF\text{-}Offs})$$

Table 5.4.2.1-1: NR-ARFCN parameters for the global frequency raster

Range of frequencies(MHz)	ΔF_{Global} (kHz)	$F_{REF\text{-}Offs}$ (MHz)	$N_{REF\text{-}Offs}$	Range of N_{REF}
0 – 3000	5	0	0	0 – 599999
3000 – 24250	15	3000	600000	600000 – 2016666
24250 – 100000	60	24250.08	2016667	2016667 – 3279165

- The RF reference frequency for an RF channel maps to a resource element on the carrier
- For each operating band a separate Δf_{Raster} (Channel raster) is defined in terms of integral multiples of Δf_{Global} (equal or larger)
  - Next slide

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Channel raster

- For each band, the Δf_{Raster} is used to increment

- For frequency bands with two ΔF_{Raster} in FR1, the higher ΔF_{Raster} applies to channels using only the SCS that is equal to or larger than the higher ΔF_{Raster} and SSB SCS is equal to the higher ΔF_{Raster}.

For example, in the n78 Khz and using 30 KHz SCS, we should use 30 KHz for the raster.

For 3.5 GHz (Center frequency), the closest Raster point is ??

NR *operating band*	ΔF_{Raster} (kHz)	Uplink range of N_{REF} (First – <Step size> – Last)	Downlink range of N_{REF} (First – <Step size> – Last)
n1	100	384000 – <20> – 396000	422000 – <20> – 434000
n2	100	370000 – <20> – 382000	386000 – <20> – 398000
n3	100	342000 – <20> – 357000	361000 – <20> – 376000
n5	100	164800 – <20> – 169800	173800 – <20> – 178800
n7	100	500000 – <20> – 514000	524000 – <20> – 538000
n8	100	176000 – <20> – 183000	185000 – <20> – 192000
n12	100	139800 – <20> – 143200	145800 – <20> – 149200
n20	100	166400 – <20> – 172400	158200 – <20> – 164200
n25	100	370000 – <20> – 383000	386000 – <20> – 399000
n28	100	140600 – <20> – 149600	151600 – <20> – 160600
n34	100	402000 – <20> – 405000	402000 – <20> – 405000
n38	100	514000 – <20> – 524000	514000 – <20> – 524000
n39	100	376000 – <20> – 384000	376000 – <20> – 384000
n40	100	460000 – <20> – 480000	460000 – <20> – 480000
n41	15	499200 – <3> – 537999	499200 – <3> – 537999
	30	499200 – <6> – 537996	499200 – <6> – 537996
n50	100	286400 – <20> – 303400	286400 – <20> – 303400
n51	100	285400 – <20> – 286400	285400 – <20> – 286400
n66	100	342000 – <20> – 356000	422000 – <20> – 440000
n70	100	339000 – <20> – 342000	399000 – <20> – 404000
n71	100	132600 – <20> – 139600	123400 – <20> – 130400
n74	100	285400 – <20> – 294000	295000 – <20> – 303600
n75	100	N/A	286400 – <20> – 303400
n76	100	N/A	285400 – <20> – 286400
n77	15	620000 – <1> – 680000	620000 – <1> – 680000
	30	620000 – <2> – 680000	620000 – <2> – 680000
n78	15	620000 – <1> – 653333	620000 – <1> – 653333
	30	620000 – <2> – 653332	620000 – <2> – 653332
n79	15	693334 – <1> – 733333	693334 – <1> – 733333
	30	693334 – <2> – 733332	693334 – <2> – 733332
n80	100	342000 – <20> – 357000	N/A
n81	100	176000 – <20> – 183000	N/A
n82	100	166400 – <20> – 172400	N/A
n83	100	140600 – <20> –149600	N/A
n84	100	384000 – <20> – 396000	N/A
n86	100	342000 – <20> – 356000	N/A

Synchronization Raster

- For faster synchronization
- More details when we look at SSB

Table 5.4.3.1-1: GSCN parameters for the global frequency raster

Range of frequencies (MHz)	SS block frequency position SS_{REF}	GSCN	Range of GSCN
0 – 3000	N * 1200 kHz + M * 50 kHz, N = 1:2499, M ϵ {1,3,5} (Note)	3N + (M-3)/2	2 – 7498
3000 – 24250	3000 MHz + N * 1.44 MHz, N = 0:14756	7499 + N	7499 – 22255
24250 – 100000	24250.08 MHz + N * 17.28 MHz, N = 0:4383	22256 + N	22256 – 26639
NOTE: The default value for *operating bands* with SCS spaced channel raster is M=3.			

Example (n78 band 3.3-3.8GHz), 100 MHz BW, 30 KHz SCS. Center Freq around 3.5

- [38.104, Table 5.3.2-1] N_{RB} = 273
- From 5.4.2.3.1, 38.104
  - The raster is 30KHz or N_{ref} step size is 2
  - the closest raster point is 633334 (NR-ARFCN)
  - Corresponds to 3500.01 MHz.
- Global Raster granularity = 15 KHZ
- 273RB = 273*12 RE * 30 KHz
- PRB mapping = floor(273/2)= 136 RB
  - 6th Sub carrier.
- 135 RB correspond to
  - 135*12*2 = 3240 ARFCN
- 6 RE correspond to 12 ARFCN

Since ARFCN corresponds to 15 KHz
Our SCS = 30 KHz