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5G NR for FRMCS: Standardisation in 3GPP

UK Sectrum Policy Forum Cluster 1 event: Future Spectrum Demand for Rail

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Agenda

- Spectrum landscape
- 5G NR for FRMCS
- Migration from GSM-R to FRMCS
- Adaptation of NR for FRMCS

Spectrum landscape and co-existence

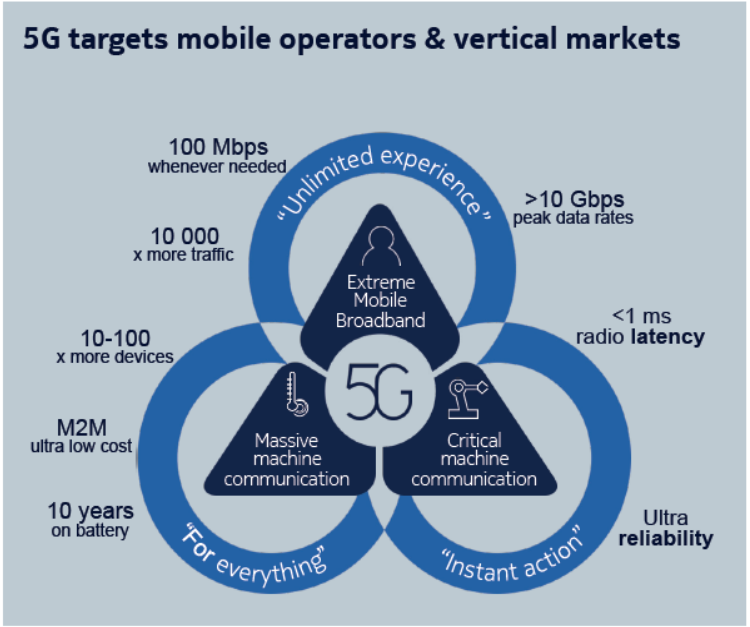
- New 3GPP NR operating bands for CEPT-designated spectrum for Railway Mobile Radio:

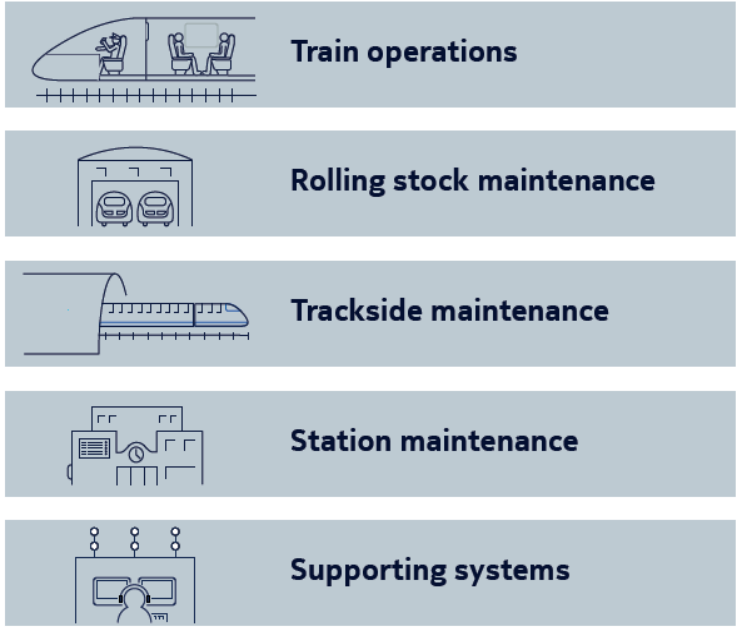
3GPP band	Duplex mode	Frequency range	Status
n100	FDD	UL: 874.4 – 880 MHz DL: 919.4 – 925 MHz	Target completion June 2022
n101	TDD	1900-1910 MHz	Completed March 2022

- 3GPP requirements ensure co-existence with adjacent spectrum, to avoid interference to/from established networks.
- European harmonized standards for type approval include additional requirements
  - e.g. base stations for band n1 (uplink 1920-1980 MHz) are required to tolerate signals in n101.

5G NR: the natural choice for FRMCS

High Capacity – Low Latency – Reliability – Security – Energy Efficiency



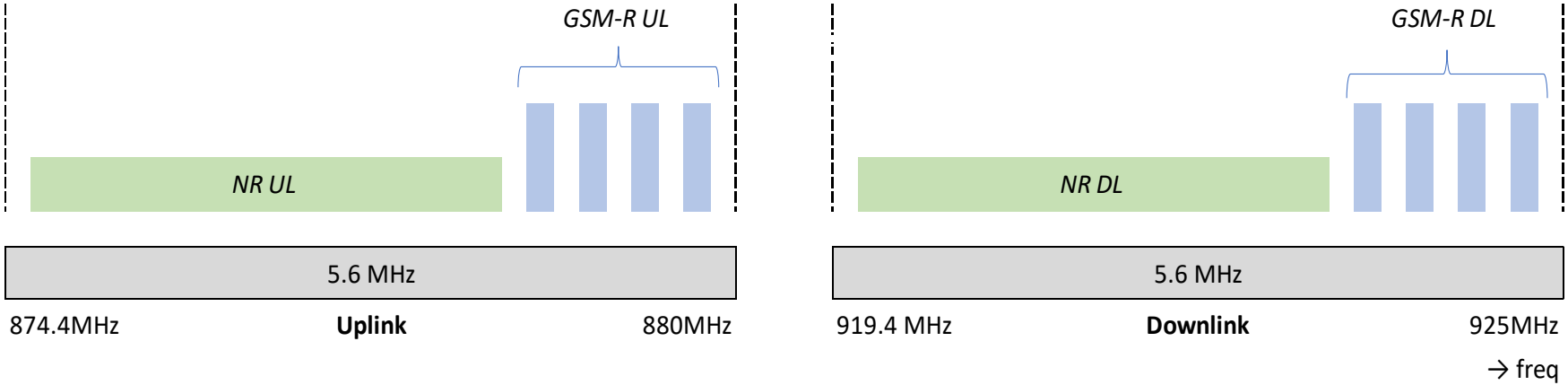


The attributes of 5G NR are the needs of FRMCS

Migration from GSM-R to FRMCS

Parallel operation 2025-2035

- Spectrum sharing:
  - Typical: 8 channels GSM-R, 4 MHz NR
  - Most challenging case: 14 channels GSM-R, 2.88 MHz NR



- As migration proceeds, bandwidth for NR can be increased

Adaptation of NR to narrow spectrum bandwidths

NR is a broadband system

- Operates most efficiently in wider bandwidths
- Minimum designed channel bandwidth = 5 MHz

NR ecosystem brings scale

- Retain fundamental NR design, especially for hardware aspects
- Ensure diversity of equipment supply and economy of scale

Challenge

- Provide an adaptation of NR for bandwidths 2.88 – 5 MHz, without impacting hardware implementations

New feature in NR Release 18: NR for dedicated spectrum < 5MHz

- Minimum necessary changes to NR, while ensuring ability to operate down to 2.88 MHz
- Target spec completion: H1 2024
- Led by Nokia & UIC

3GPP A GLOBAL INITIATIVE

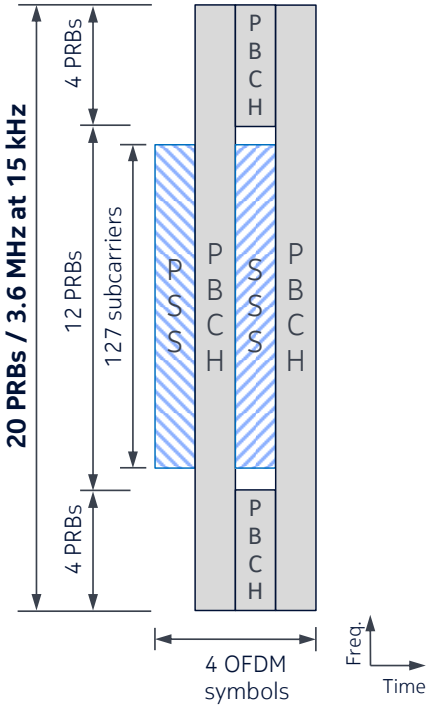
Common goals with other critical industries:

- Smart utility grid control
- PPDR

Both have instances of 2x3 MHz FDD spectrum

A closer look

Synchronization Signals and Broadcast Channel



* 1 Physical Resource Block (PRB) = 12 x 15 kHz subcarriers = 180 kHz

Synchronization signal/PBCH block (SSB) is a core component of NR.

- Used for
  - initial cell search and selection
  - beam and cell measurements
  - radio link monitoring.

SSB consists of

- Primary and Secondary Synchronization Signals (PSS and SSS) for time and frequency synchronization and providing physical layer cell ID
- Physical Broadcast Channel (PBCH) carrying Master Information Block (MIB) that contains critical information needed to access the cell

Synchronization signals fit, but PBCH does not!

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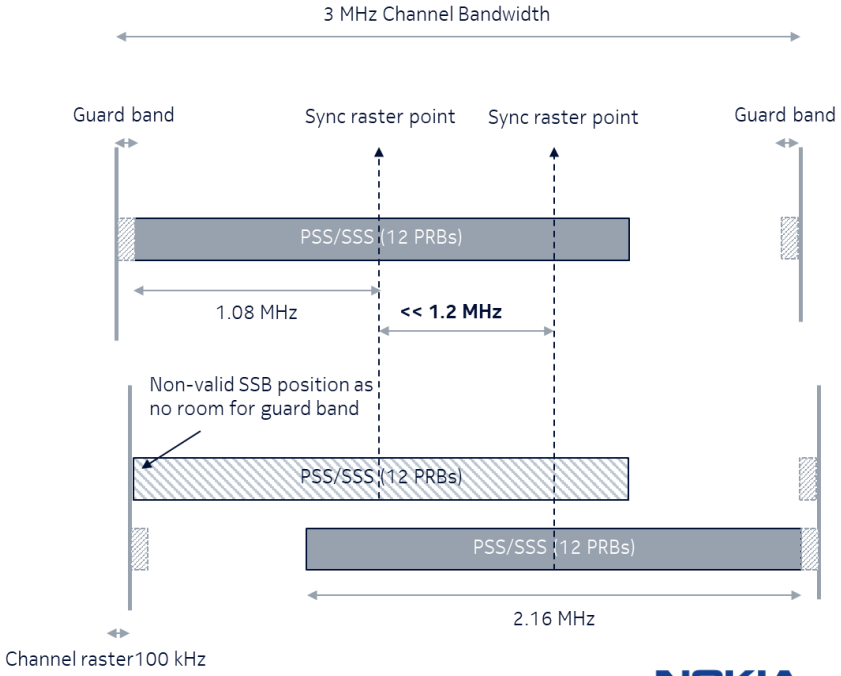
Channel Raster and Synchronization Raster

- NR channel raster:
  - Set of potential centre frequencies for an NR carrier
  - Spacing of 100 kHz spacing => no problem for FRMCS
- Synchronization raster:
  - Set of potential positions for SSB
  - Much sparser than channel raster (to expedite cell search)
    - Clusters of three positions every 1.2 MHz
    - Too sparse to support efficient NR carrier positioning within the narrow bandwidths available for FRMCS.

NR synchronization raster needs to be modified

Example: Shifting the channel bandwidth by 100kHz makes it impossible to find a valid sync raster position:



PBCH bandwidth

PBCH occupies 3.6 MHz

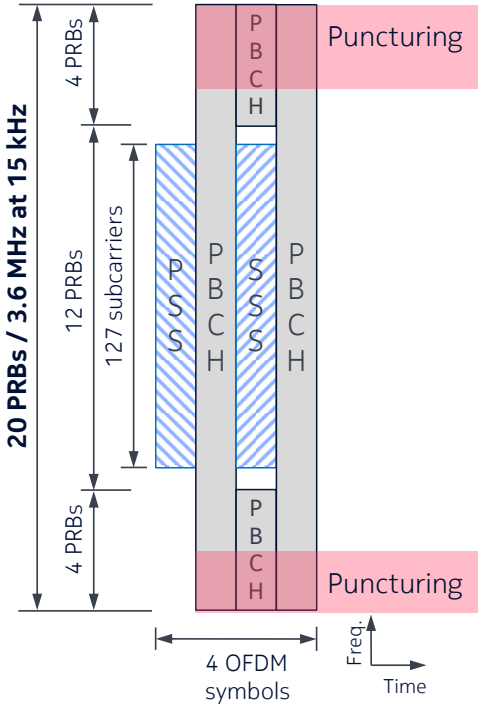
- Bandwidth needs to be narrowed
- E.g. 15 PRBs occupies 2.7 MHz

Puncturing is the preferred way to narrow the PBCH bandwidth

- Puncturing is a simple operation with mininal impact on implementation
  - NR base station simply blanks the signal mapped on the edge PRBs outside the available bandwidth.
  - Correspondingly, UE may simply null the punctured PRBs at the receiver.
  - Otherwise, signal processing can be kept unchanged.

But:

Puncturing weakens the encoding for PBCH payload => performance loss.



Punctured PBCH performance

	PBCH size in frequency		
	18 PRBs	15 PRBs	12 PRBs
Change in link budget when **UE is unaware** of PRBs punctured [dB]	-0.7	-2.6	-5.6
Change in link budget when **UE is aware** of PRBs punctured [dB]	-0.5	-1.4	-3.7

Assumptions:

- 3GPP compliant simulator
- Two Tx and two Rx antennas
- No interference on punctured PRBs – only noise.
- PBCH tx power assumed constant (i.e. PSD is increased with puncturing)

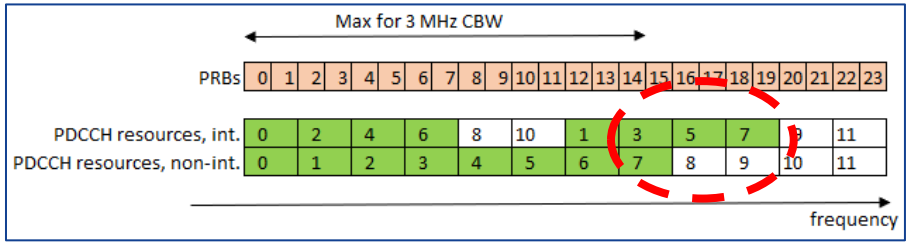
- UE awareness of which PRBs are punctured reduces the loss from puncturing.
  - Difference can be larger if the UE receives interference from e.g. GSM-R on the punctured PBRs.

UEs should be aware of the applied PBCH puncturing pattern

- Sync raster could be used to indicate the puncturing
- Remaining loss could be mitigated by:
  - Increased PBCH transmission power
  - Increased antenna gain

Downlink Control Channel

- After detecting PBCH, UE can monitor the Physical Downlink Control CHannel (PDCCH)
  - carries scheduling information for other downlink transmissions
- Monitored PDCCH space spans at least 24 PRBs = 4.32 MHz
  - PDCCH for the largest coverage (i.e. occupying 3 OFDM symbols) is interleaved over 20 PRBs = 3.6 MHz within the monitored resources



Some modifications will be needed to the PDCCH

- Some puncturing of PDCCH is needed
- Configuration options for frequency offset between SSB and monitored PDCCH resources should also be reconsidered

Other channels and signals

Physical Random Access Channel (PRACH)

- Supports multiple formats targeted at different use cases and coverage requirements
  - PRACH Format 3 designed for high-speed users occupies >4 MHz.
  - But PRACH Format 0 can support high UE speeds at 900 MHz carrier frequency with some reduction in sensitivity compared to PRACH Format 3.
  - Other PRACH formats can fit in 3 MHz bandwidth.

Other NR channels and signals can be configured sufficiently flexibly for functional operation of NR.

There is no absolute need to modify any other NR channels to support bandwidths below 5 MHz

Summary

- 3GPP defines bands n100 and n101 for 900 MHz and 1900 MHz FRMCS spectrum respectively
- 5G NR's capabilities satisfy well the requirements of FRMCS
- Migration from GSM-R to FRMCS will require a decade of parallel operation
- During migration, spectrum available for NR will be less than the original minimum design bandwidth of NR
- 3GPP Rel-18 / 5G-Advanced is specifying necessary modifications to NR to enable operation in bandwidths down to around 3 MHz
  - Necessary changes are minor
  - Hardware implementation impacts will be avoided to build on the established NR product ecosystem
  - Performance impacts are small and can be mitigated
  - Specifications scheduled to be complete by H1 2024

Size of 900 MHz band poses challenges for migration to FRMCS.
But 3GPP is working to ensure 5G NR will be ready.

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