5G NR base-stations redefine the SDR paradigm

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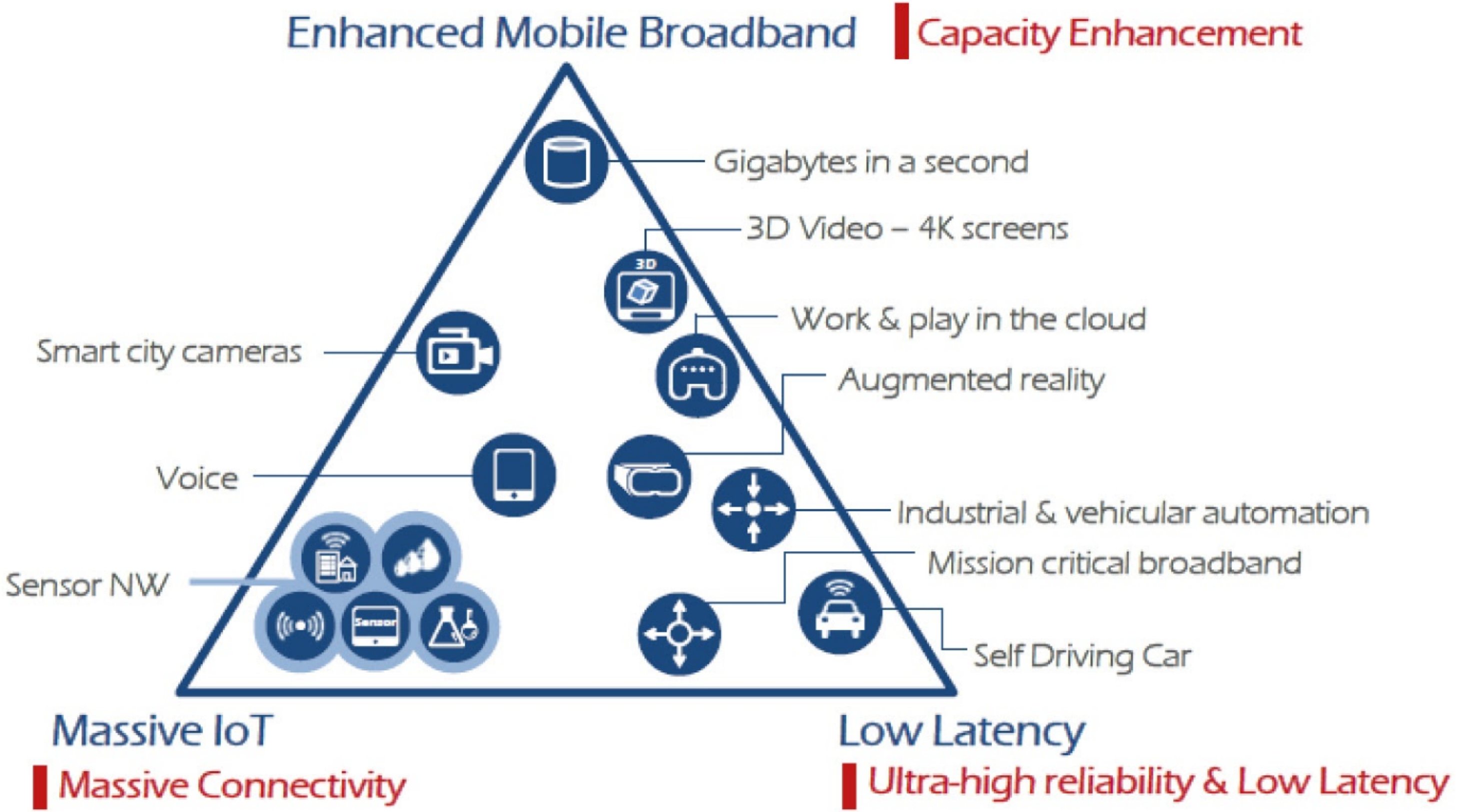
Impact on SDR architecture and SW/HW partitioning

CEVA’s Solution for 5G baseband

5G Very Diverse Use Cases

The main 5G goal is to enable new kinds of services, connect new industries, and empower new user experiences. Existing and new use cases vary greatly across market segments

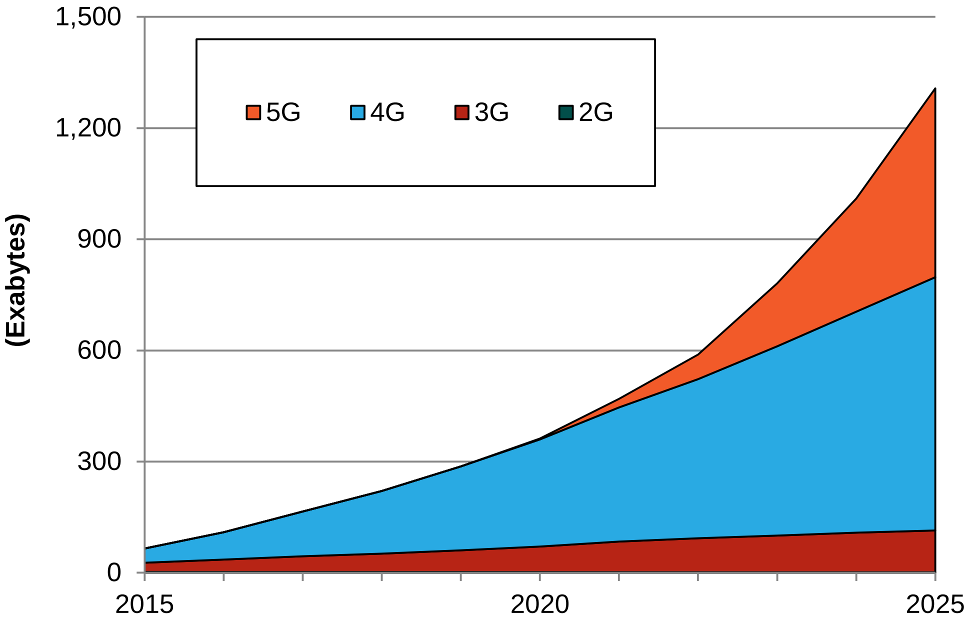
5G New Uses Cases Mapped by Requirements



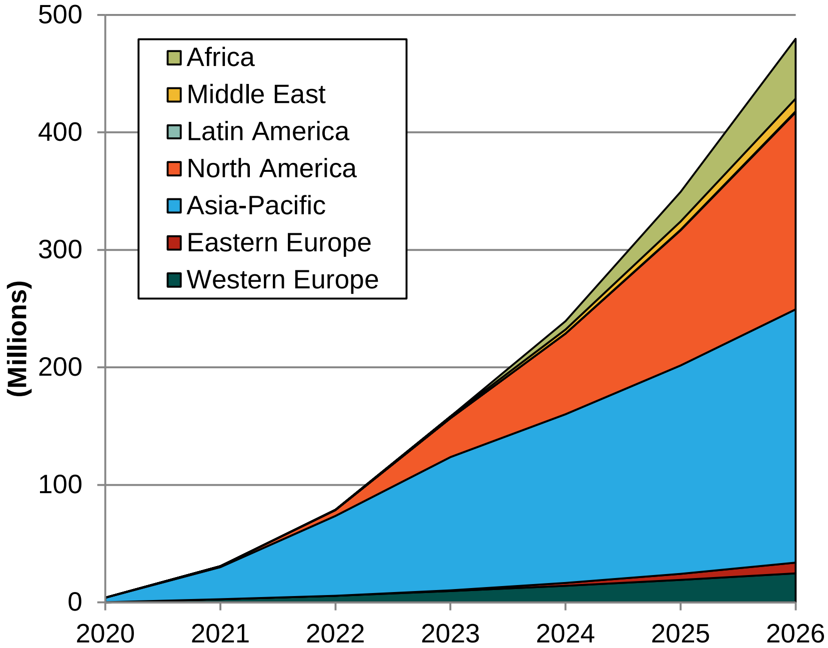
The 5G Opportunity

By 2025, 5G Mobile Data Traffic will represent 40% of Total Data Traffic and Subscriptions will reach 500 million

Mobile Data Traffic by Technology



5G Subscriptions by Region



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The Advent of 5G

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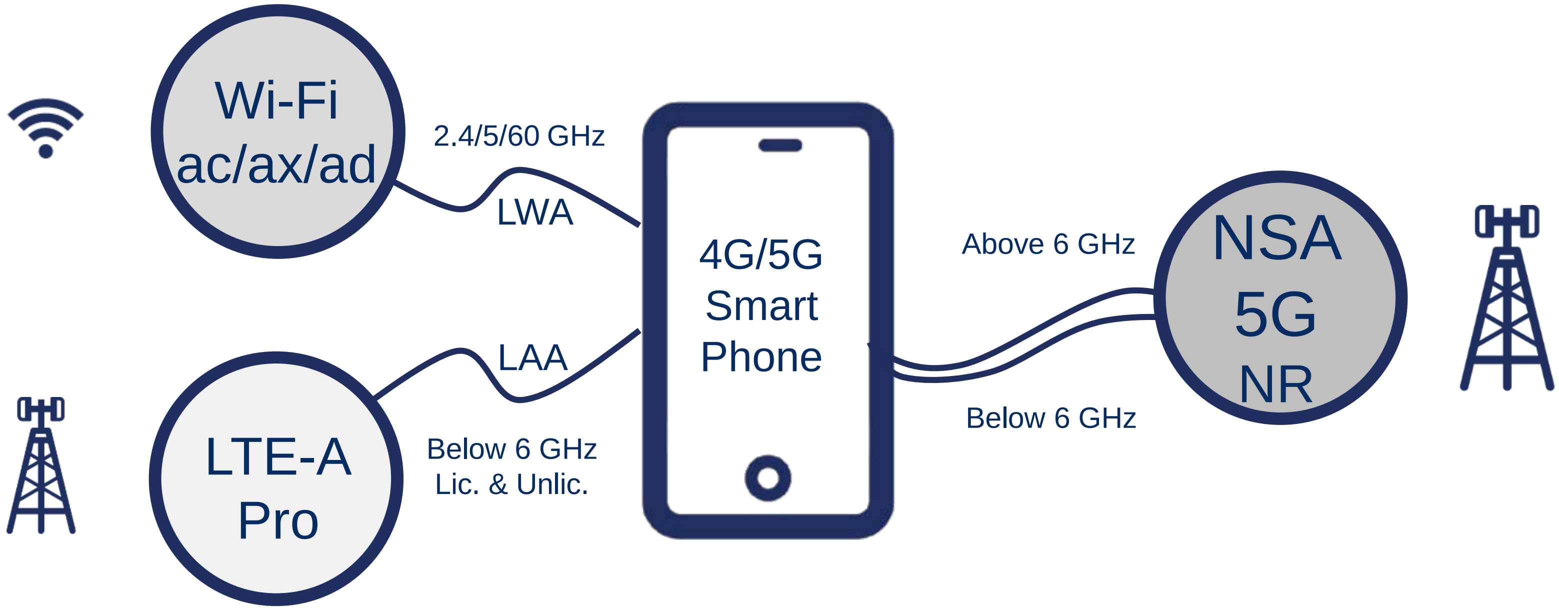
- A unified protocol bringing together a massive number of users with requirements as diverse as MTC and eMBB (enhanced Mobile Broadband)
- Supports new use cases that LTE could not support such as VR, V2X, eHealth, Mission Critical Emergency
- Compatible with previous generation LTE and LTE-A Pro Network Infrastructure (Core and RAN)
- Seamlessly aggregates very diverse frequency bands from 400MHz to 80GHz and bandwidths from 20 to 800 MHz using LTE, LTE-A Pro, 5G NR, Wi-Fi 11ax/ad with a unified protocol

A wireless standard so advanced compared to previous generations that it needs a new processing approach to ensure its success…

Non Stand-Alone (NSA) 5G NR

Multi-RAT Aggregation of Multi-Gigabit Connectivity

Multi-Gig technologies co-existing to achieve higher data rate



The Need for Multi-Gig Wireless

The ever-increasing need for higher data rates calls for a scalable and flexible standard and technology tool box that can:

1. Facilitate Aggregation

- Of radio carriers/bands of different width either licensed or unlicensed from 400MHz up to 80GHz mmWave
- Of various technologies such as LTE, LTE-A Pro, Wi-Fi 11ac/ax, WiGiG to provide a seamless unified data pipe

2. Reduce Latency

- Reduced LTE latency brings 8x better network responsiveness to V2X, VR, mobile gaming and mission critical emergency

3. Utilize Massive MIMO Technology

- Greatly increases LTE network capacity and coverage
- Operators want to support huge numbers of users and IoT devices at once

4. Improve reliability and encryption

- Enables mission critical usage such as Cellular V2X (C-V2X), eHealth and Industrial IoT

5G – Diverse Spectrum

CEVA

5G NR

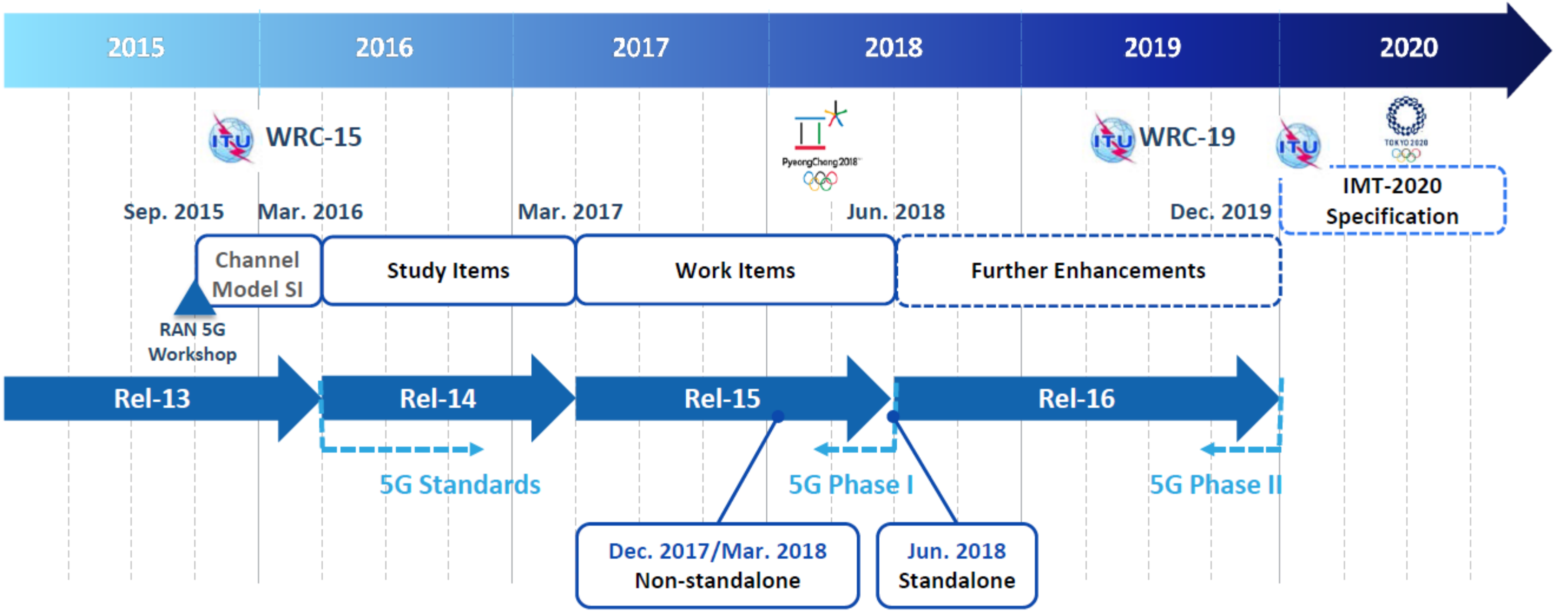
Low bands below 1 GHz: longer range for e.g. mobile broadband and massive IoT
e.g. 600 MHz, 700 MHz, 850/900 MHz

Mid bands 1 GHz to 6 GHz: wider bandwidths for e.g. eMBB and mission-critical
e.g. 3.4-3.8 GHz, 3.8-4.2 GHz, 4.4-4.9 GHz

High bands above 24 GHz (mmWave): extreme bandwidths
e.g. 24.25-27.5 GHz, 27.5-29.5, 37-40, 64-71 GHz

Licensed Spectrum	Shared Spectrum	Unlicensed Spectrum
Exclusive use	New shared spectrum paradigms	Shared use

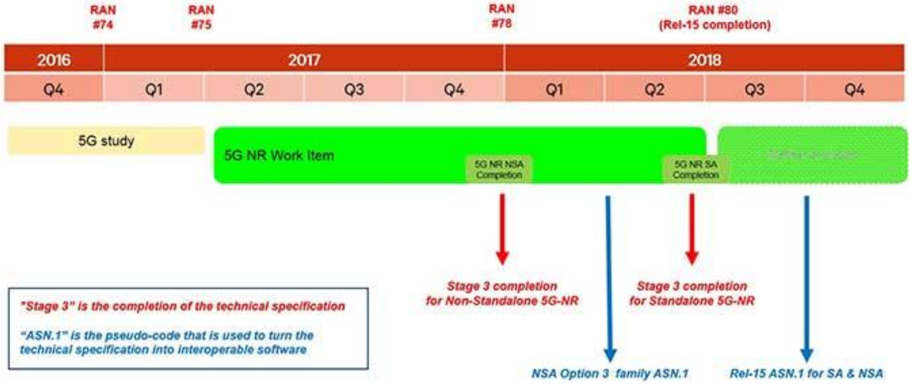
5G Timeline



2015
2016
2017
2018
2019
2020
WRC-15
PyeongChang 2018
WRC-19
TOKYO 2020
Sep. 2015
Mar. 2016
Mar. 2017
Jun. 2018
Dec. 2019
IMT-2020 Specification
Channel Model SI
Study Items
Work Items
Further Enhancements
RAN 5G Workshop
Rel-13
Rel-14
Rel-15
Rel-16
5G Standards
5G Phase I
5G Phase II
Dec. 2017/Mar. 2018 Non-standalone
Jun. 2018 Standalone

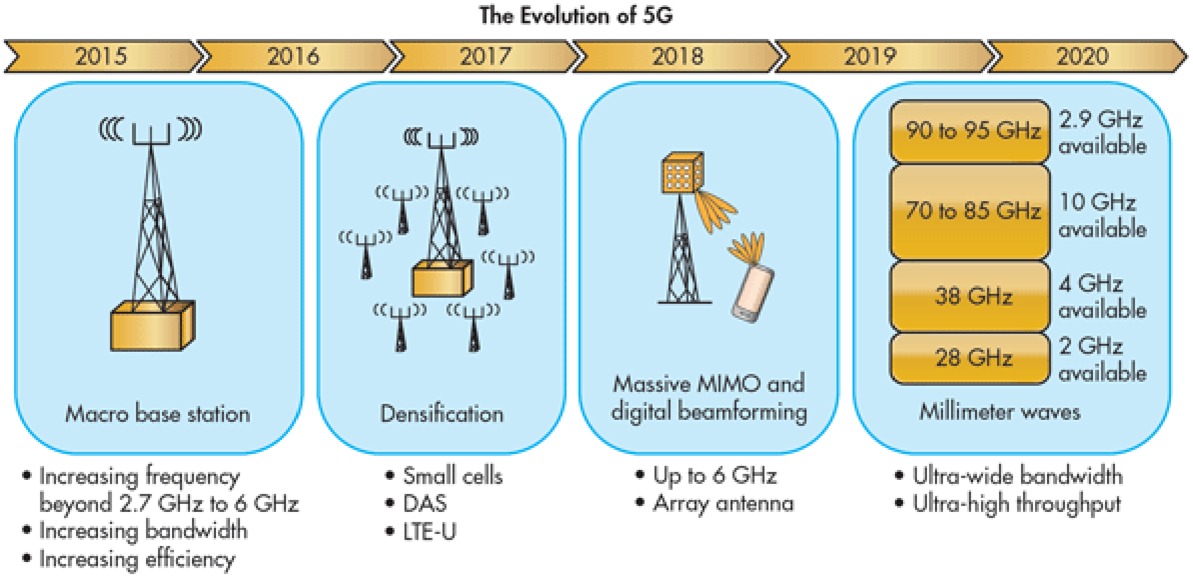
5G Release-15 Deployment Stages

- Pre-Standard V5GTF
  - Verizon and KT released V5GTF, a 5G pre-standard by Mid 2016
  - Addresses the FWA (Fixed Wireless Access) use case for residential broadband
  - Will represent the first commercial deployment of millimeter waves for cellular
- Non Standalone NSA 5G NR
  - Addresses the enhanced Mobile BroadBand (eMBB) use-case.
  - NSA mode connections will be anchored in LTE while 5G NR carriers are used to boost data-rates and reduce latency in 3.3GHz to 40GHz bands
  - Complete (ASN.1) by March 2018
- Standalone SA 5G NR
  - SA mode will cover all 5G use cases in all bands
  - Complete (ASN.1) by Sept 2018



5G Timeline vs New BTS Technology

5G Base-station technology required by each 5G standardization release



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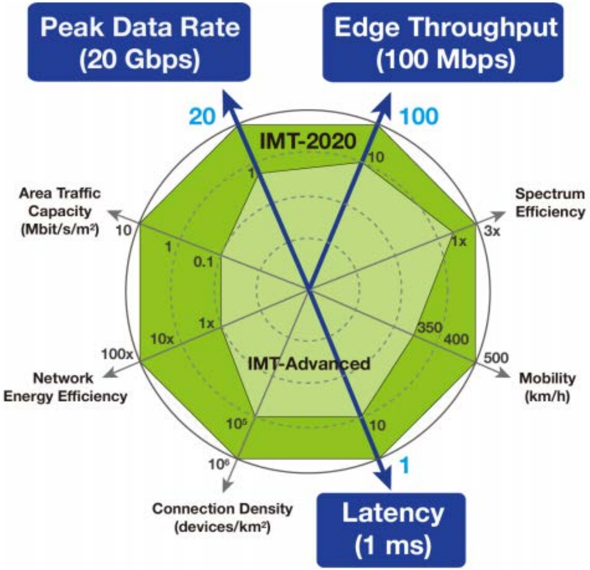
5G NR Base Station (gNB) Requirements

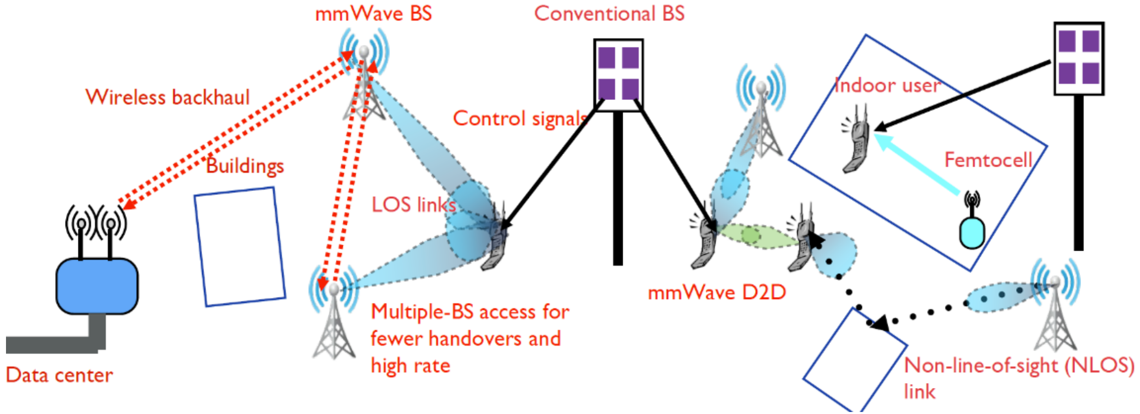
- Very High Throughput - up to 20Gbps
- Extreme Low Power (mW/bit)
- Very Low Latency (<1ms)
  - In URLLC less then 0.5ms
- Massive MIMO and Advanced Beamforming techniques to increase traffic capacity
- Massive Number of Users
  - From 100K to 1M MTC devices per cell



5G NR gNB Requirements – 2/2

- The gNB needs to support multiple and combined Tx/Rx cases:
  - Multi-User MIMO Cases
  - Massive number of users upon IoT device deployment
  - Multi Bands Cases (sub 6GHz, above 6GHz, mmWave)
  - Multi Bandwidth cases that depend on the sub-carrier spacing ($15 * 2^N$,15KHz up to 480KHz)

All cases can be combined dynamically!



5G NR gNB Challenges – 1/3

- Ultra low latency requirement
  - Data processing should be completed within a very short time
    - Depends on the frame structure and numerologies.
    - The worst case is one symbol latency - for example 4.46usec latency with sub-carrier spacing of 240KHz
  - Control channel decoding is also under very tight latency budget
- Massive MIMO (256+ gNB antennas)
  - Requires state-of-the-art algorithms for handling massive reception
  - Advanced Beamforming techniques – (Analog/Digital/Hybrid Beamforming)
  - MU-MIMO advanced algorithm techniques

5G NR gNB Challenges – 2/3

- 3GPP 5G NR – a flexible standard that will continuously evolve
  - Flexible numerology – supporting mmWave, sub/above 6GHz bands, different sub-carrier spacing. Mixed numerologies also need to be considered
  - Need to support flexible frame structure and new radio access technology – number of symbols in a slot, mini slots, many DMRS location options, etc
  - Flexible Beamforming, Massive MIMO, MU-MIMO mechanisms will very with gNB deployments
- Massive control operations
  - Resource sharing – size and power constraint
  - Flexible and dynamic reconfiguration is needed (Uplink/Downlink).

5G NR gNB Challenges – 3/3

- PHY control needs to handle DSP tasks in an efficient manner:
  - Measurements, Power Control, CSI (Channel State Information), BSI (Beam State Information), AGC calculation, etc.
  - High scheduling complexity
- High density devices
  - High noise interference – accurate CSI is needed
  - Accurate Beamforming requirement.

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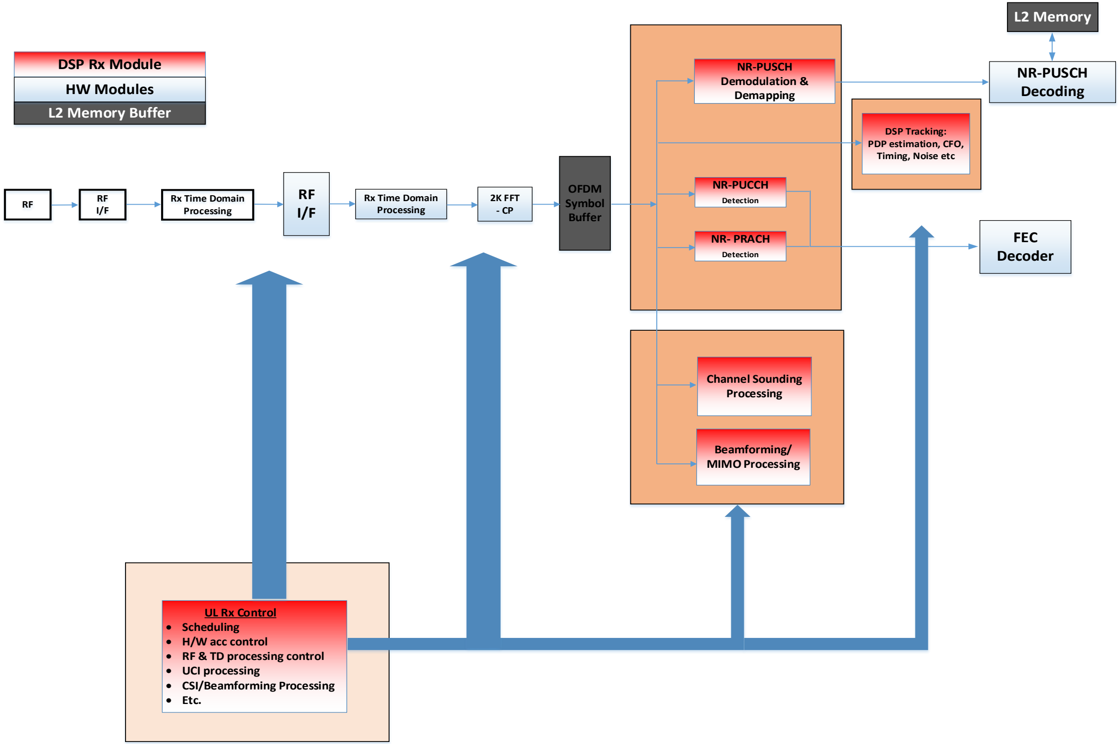
5G NR gNB Task Requirements

- We can separate the gNB processing into several tasks
  - Data path processing: NR-PUSCH, NR-PUCCH, NR-RACH, etc.
    - Modulation and demodulation of physical channels
    - Soft bit processing including HARQ and Rate matching
    - FEC encoding/decoding of the transport channel (LDPC & Polar Codes)
  - Beamforming, CSI handling, Sounding, Channel Measurements etc.
    - Radio channel measurements – DSP tracking
    - Massive Multiple Input Multiple Output (MIMO) antenna processing
    - Digital and Analog Beamforming/Hybrid beamforming - (Rx & Tx)
  - PHY Control
    - Scheduling
    - RF configuration
    - AGC
    - H/W modules configuration and control

5G NR gNB Task Requirements - 2/2

HW and SW module and task partitioning



Balanced HW/SW partitioning

- Maintain SW flexibility to allow key algorithms upgrade and evolution
  - Offer solution differentiation – dynamically balance HW/SW partitioning
  - Updates for new standard releases, new features, new modules (RF/ Analog), channel conditions and higher performance/quality
- Extreme low latency requirements while handling Multi-Giga bit channel, requires a centralized architecture to avoid Core-to-Core transactions
  - High processing capabilities in centralized core in addition to the ability to reduce control overhead
- Handling multiple RF chains requires a flexible up-scaling – core inter-connection buses need to be supported.
- High complexity and low flexibility algorithms are implemented in HW offering reduced Power and Cost

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5G NR NR-PUSCH Use Case Example

Use Cases Challenges are:

- Very short symbol latency
- Throughput of 3 Gbps
- 4 UEs (MU-MIMO)

This Use case is based on 3GPP definition of NR Release 15 (RAN WG1 #87)

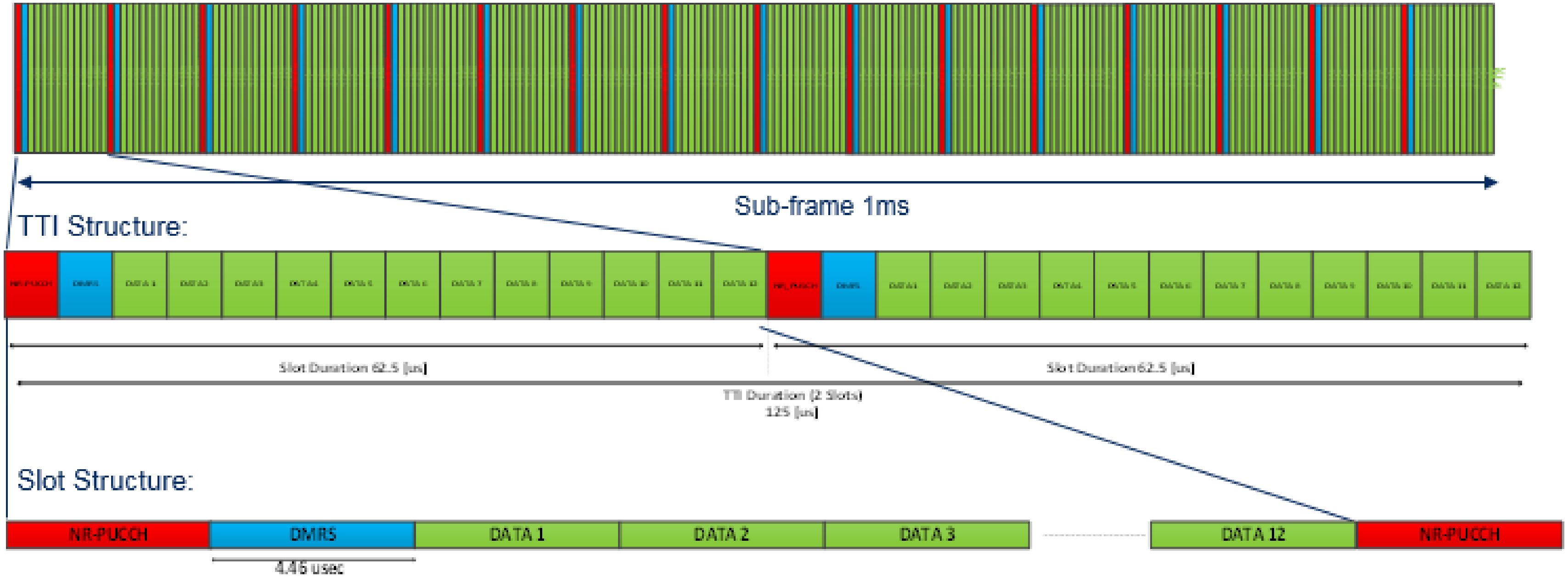
Parameters	Definition
Carrier Frequency	28GHz
Duplex Mode	TDD
Channel Bandwidth (per CC)	320MHz
Sampling Frequency	491.52 MHz
MIMO Configuration	2x2
Base Station Antennas	64
Subcarrier Spacing	240 KHz (15KHz * 2^4)
Used Subcarriers	1200
OFDM Symbol duration (+CP)	4.46 us
TTI Duration (2 Slots)	125us (2x14 Symbols)
Modulation	64QAM
Throughput per 1 UE	~3Gbps
Number of UEs	4

Slot Structure:

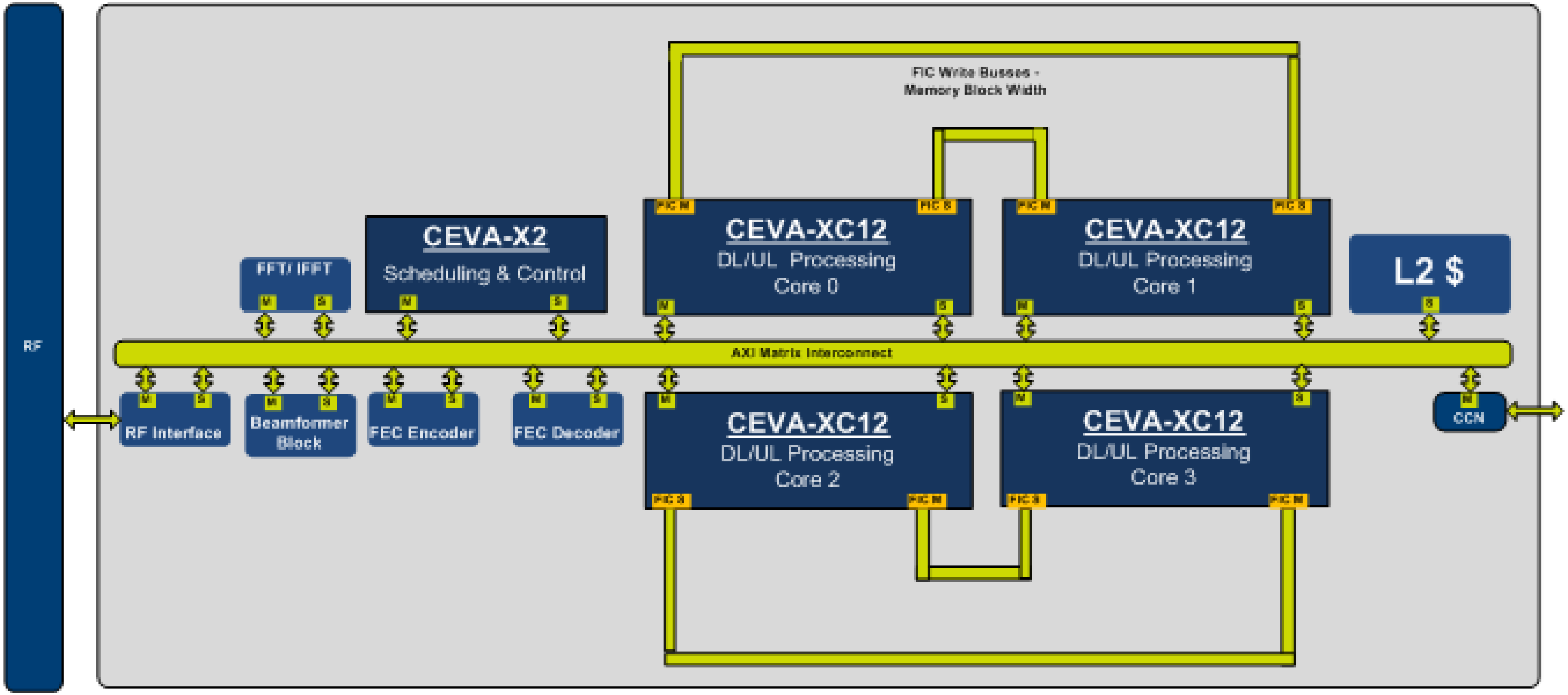
5G NR - Frame structure

The frame duration in NR-5G is 1ms. In the use case configuration the TTI duration (Tx-Rx structure granularity) is 125usec. The frame structure contains 2 slots.

The NR-PUSCH is following the DMRS for the PUSCH symbols and the NR-PUCCH.



5G NR gNB Cluster Architecture



5G NR gNB Architecture Highlights

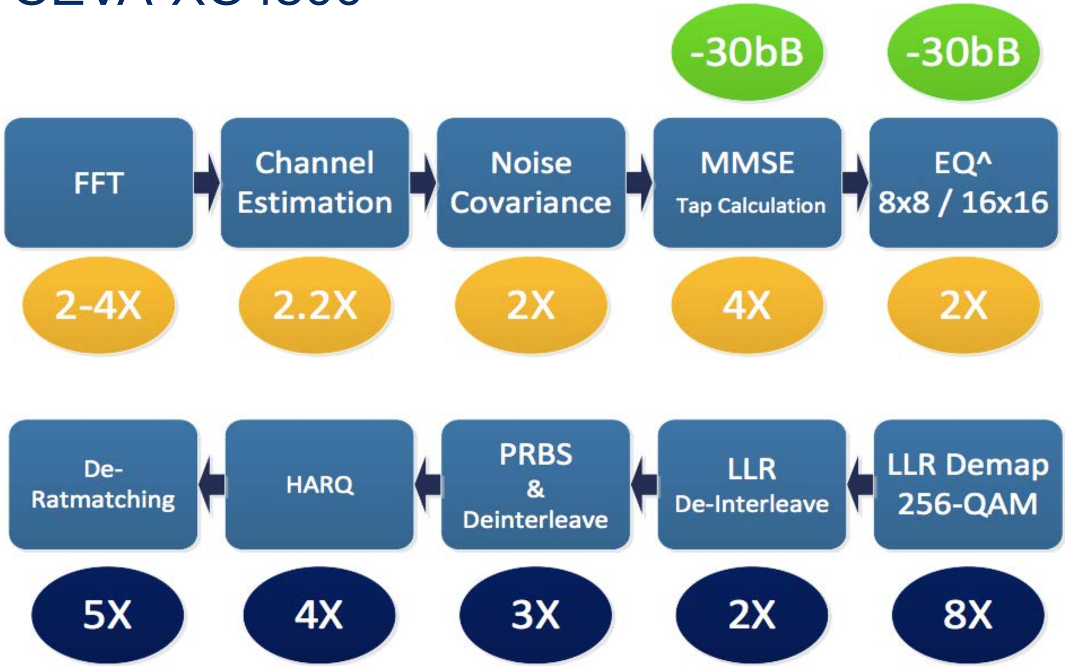
- Each 5G NR carrier (320MHz) is processed using a single cluster
  - Contains 4xCEVA-XC12 Cores
- Each pair of CEVA-XC12 cores are connected using FIC buses
  - Allows CEVA-XC12 core in a core pair to access the memory blocks of the other core
- Front End FFT/ IFFT for all Rx/Tx antennas are implemented in HW
  - Including CP removal / addition
  - Assuming processing latency for 1 symbol over all the Rx/ Tx antennas is 1 Symbol duration (~4.46 us)
- FEC Decoder/ Encoder are implemented in HW

CEVA-XC12 Multi-core processing

- Low latency and high throughput multi-core data communication is essential to efficiently process a task in a multi-core fashion
- The architecture is designed to allow a core pair to share the same task processing workload
  - E.g. Channel Estimation processing or Single Data Symbol processing
- Cores will exchange intermediate results of their calculation:
  - Channel Estimates of different Rx Antenna ports
  - MMSE Taps of different subcarriers
  - Noise Covariance matrix of different Resource Blocks
  - Result of the preceding module in a sequential processing flow

CEVA-XC12 Performance

- The CEVA-XC12 is equipped with advanced processing engines and new instructions to speed up many UL reception tasks versus previous generation CEVA-XC4500



Thanks!

Q & A

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