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Carrier Aggregation and Dual Connectivity

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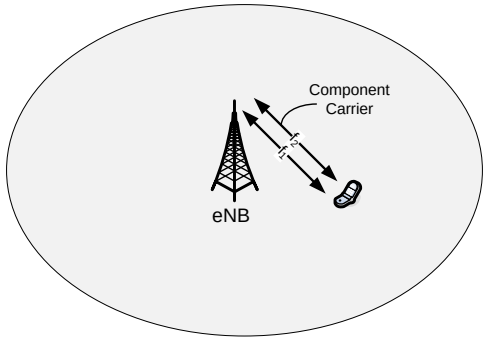
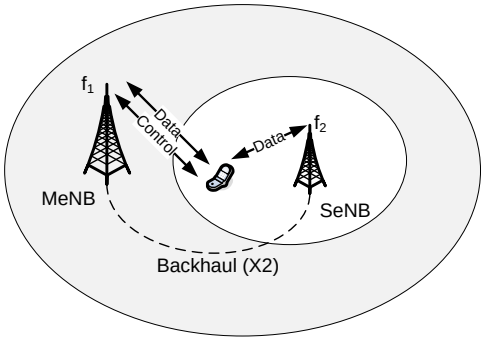
Carrier Aggregation and Dual Connectivity

- Carrier Aggregation (CA) was introduced in 3GPP to allow a UE to simultaneous transmit and receive data on multiple component carriers from a single eNB
  - CA can increase user throughput as the aggregated bandwidth is increased
- Dual Connectivity (DC) was introduced in 3GPP to allow a UE to simultaneously transmit and receive data on multiple component carriers from two cell groups via master eNB (MeNB) and secondary eNB (SeNB)
  - DC can increase user throughput, provide mobility robustness, and support load-balancing among eNBs



Carrier Aggregation



Dual Connectivity

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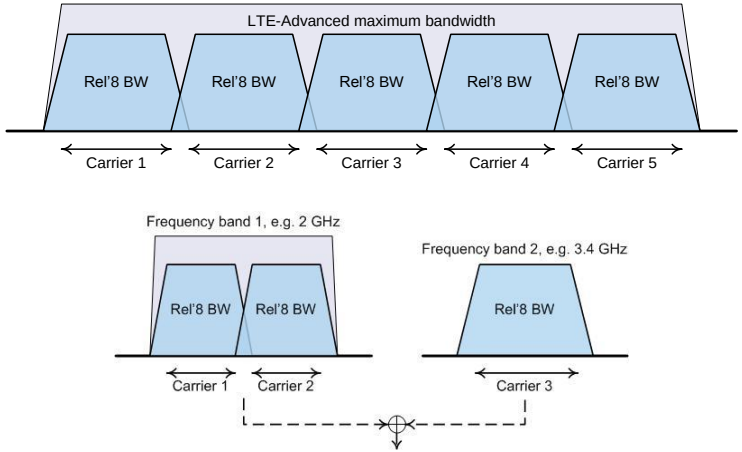
Carrier Aggregation

- Carrier aggregation (CA) allows combining of multiple component carriers
  - Increasing bandwidth and enhancing data rates for users.
  - Support for non-contiguous CA to more efficiently utilize fragmented
    frequency resources – more options for spectrum re-farming.
  - Multiplexing gain by dynamically distributing traffic over multiple carriers.
- LTE-A supports CA of up to 5 carriers while LTE-A Pro supports CA of up to 32 carriers
- LTE-A also allows CA of TDD and FDD carriers, inter-band TDD CA with different UL-DL configurations, and CA with multiple uplink timing advance values.
- CA provides the basic framework for Licensed Assisted Access (LAA) where LTE is deployed in unlicensed band as a secondary cell



Release	Max No of Carriers	Peak DL Rate	
		2x2 MIMO	8x8 MIMO
LTE-A	5 (up to 100 MHz)	~1 Gbps	~3.9 Gbps
LTE-A Pro	32 (up to 640 MHz)	~6.3 Gbps	~25.1 Gbps

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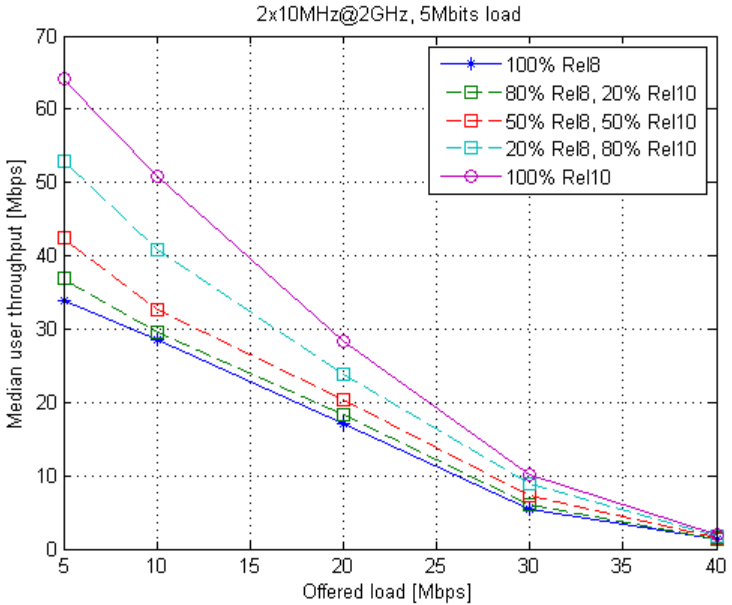
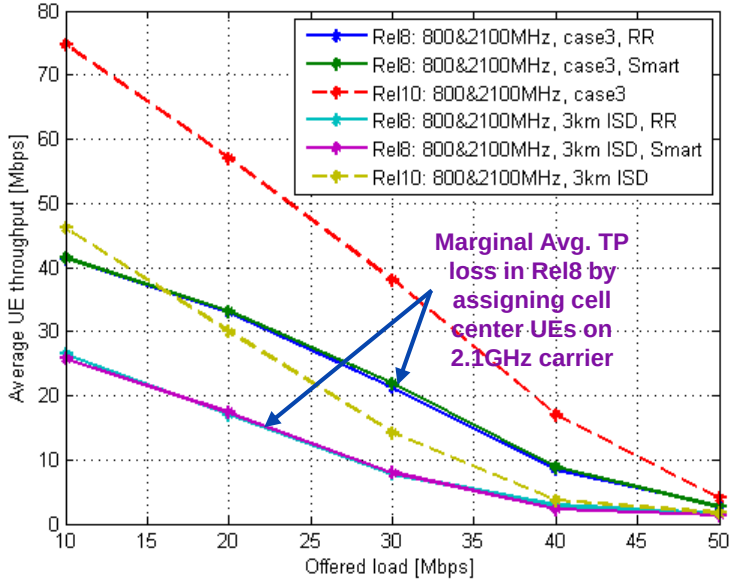
CA Performance

- User performance with intra-band and inter-band carrier aggregation –



2x10MHz, 2 GHz, median user throughput



2x10MHz, 2.1 & 0.8 GHz, mean user throughput

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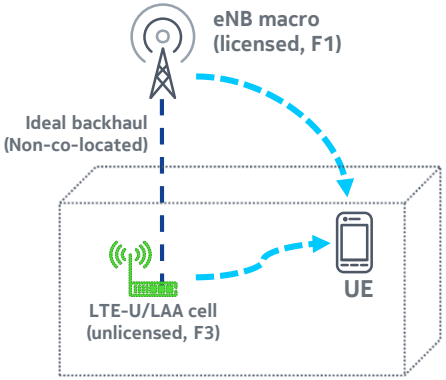
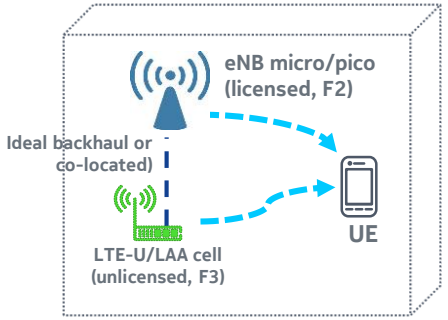
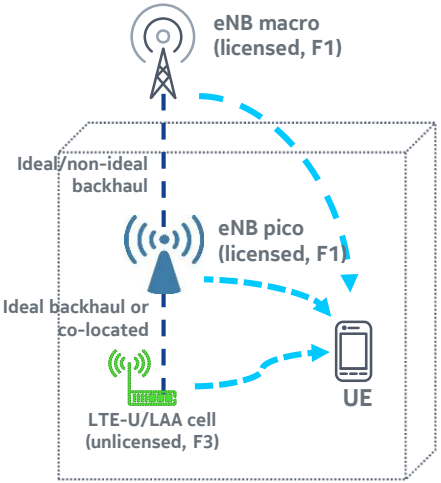
LTE-U/LAA deployment scenarios

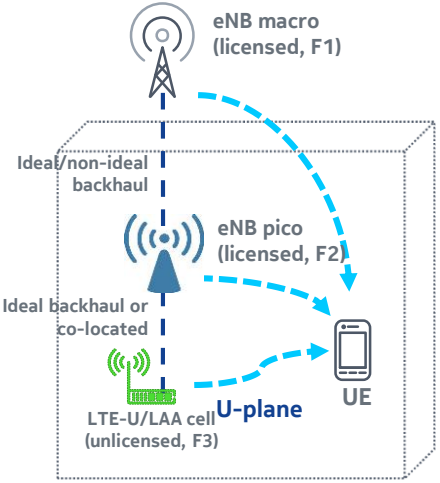
Use cases

- The main application areas are **outdoor and indoor public small cells and corporate cells**
- LTE-U and LAA are always **co-located** (or connected via ideal backhaul, i.e. baseband is co-located) **with a licensed carrier**
- LWA also includes scenarios where the licensed carrier is not co-located with Wi-Fi with non-ideal backhaul between the cells.









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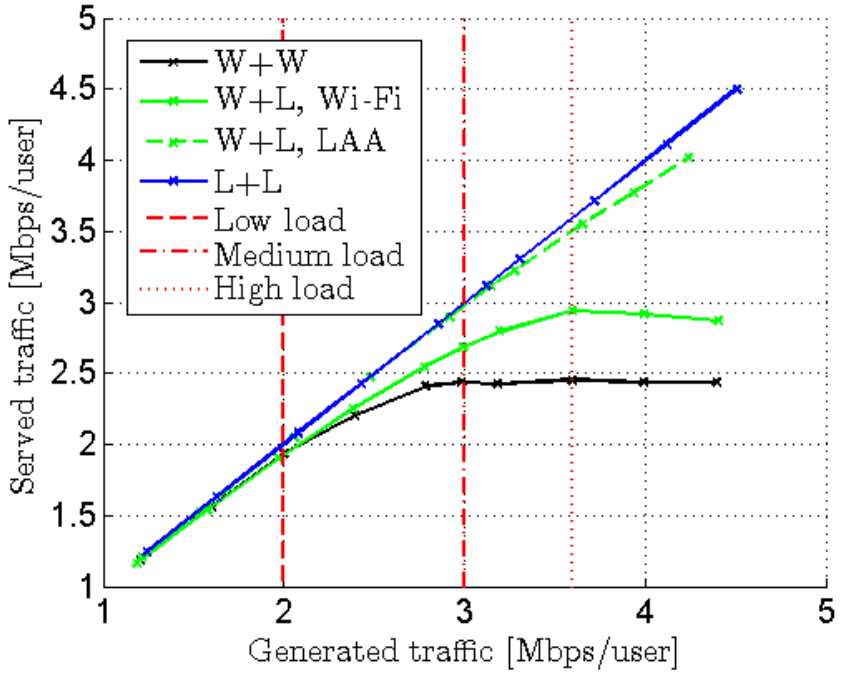
Indoor scenario with DL only traffic: loading

- W+W means 2 Wi-Fi operators
- W+L means 1 Wi-Fi and 1 LAA operator
- L+L means 2 LAA operators
    - LAA operators are asynchronous
- Definition of fairness: performance of the first Wi-Fi operator does not decrease when the second operator's Wi-Fi is replaced with LAA

Low/medium/high loading is defined in 3GPP by buffer occupancy ranges of the first operator in the W+W case.

The definition is a little unfortunate, as Wi-Fi is noticeably overloaded already at medium load.

Loading per cell = Loading per user * 2.5



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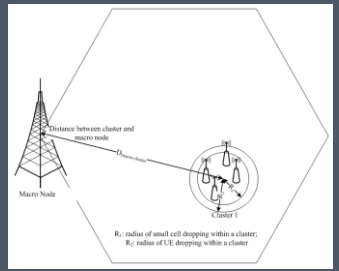
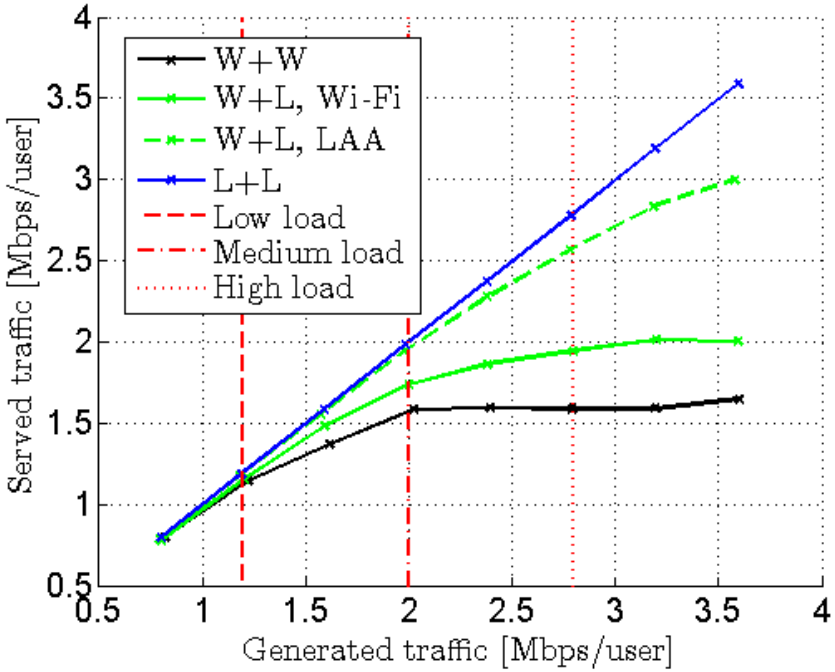
Outdoor scenario with DL only traffic: loading

There is more interference in the outdoor scenario, and possibly longer distances to own AP/eNB.

Fairness and performance trends are similar to what we see in indoor scenario.

Outdoor scenario:
- 21 sites, 500m ISD
- One cluster per site, 140m diameter
- 4 APs/eNBs per cluster/operator
  - 20m minimum intra-op. distance
  - 10m minimum inter-op. distance
- 10 users per cluster/operator
- 20MHz unlicensed band
- 18dBm + 5dBi





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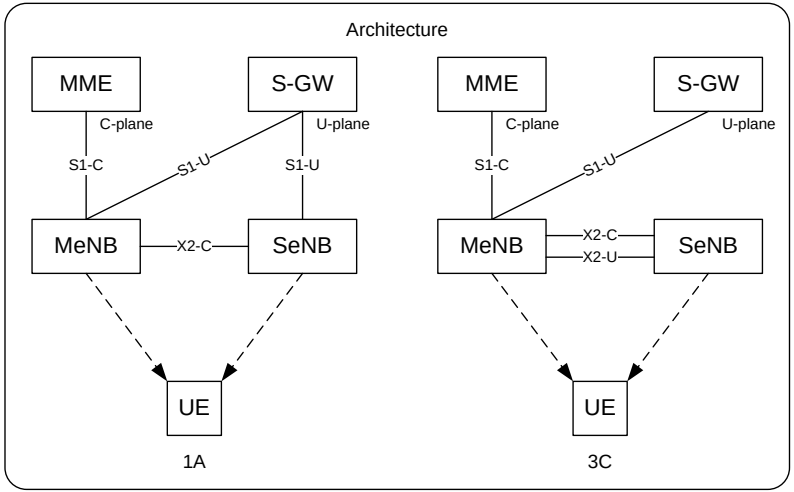
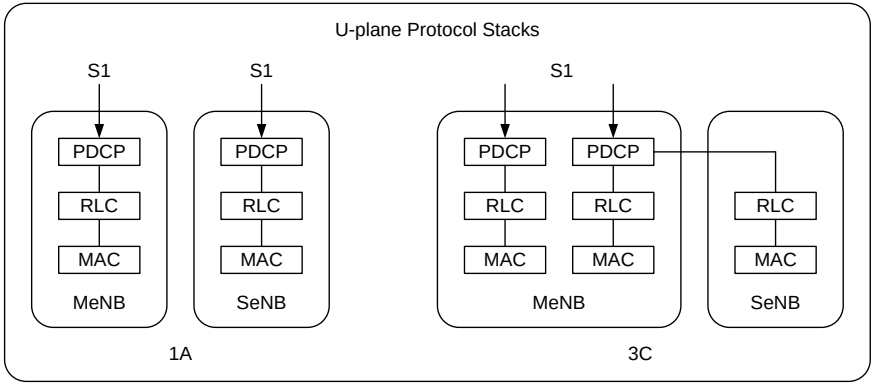
Dual Connectivity Architecture

- Only one C-plane S1-MME connection per UE
  - RRC connection via MeNB only, SeNB connection is controlled through MeNB
- Two DC user-plane architecture options are supported -
  - 1A – S1-U termination at MeNB and SeNB (analogous to carrier aggregation)
  - 3C – S1-U termination at MeNB, bearer split in RAN (analogous to off-loading)





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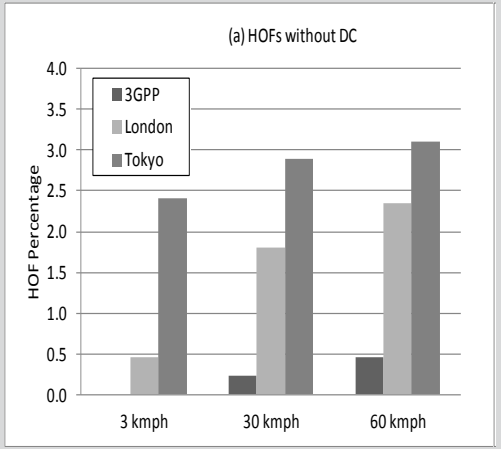
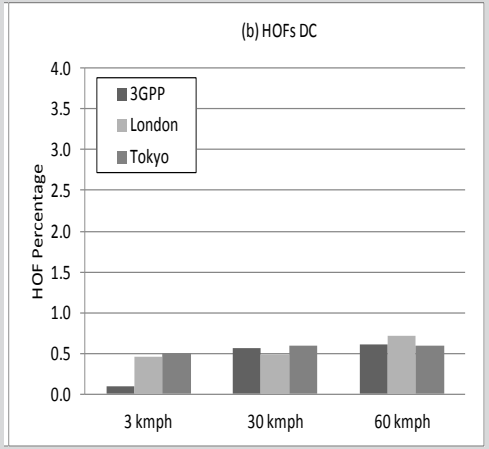
Mobility Robustness with Dual Connectivity

- Study of handover failures with dual connectivity - considerably less handover failures with dual connectivity since UE remains connected to macro-cell

Without Dual Connectivity



With Dual Connectivity



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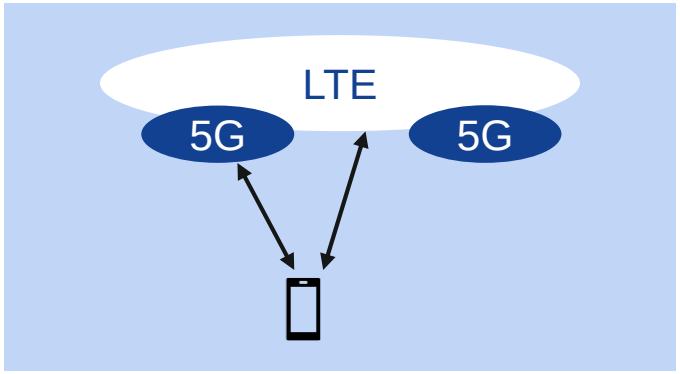
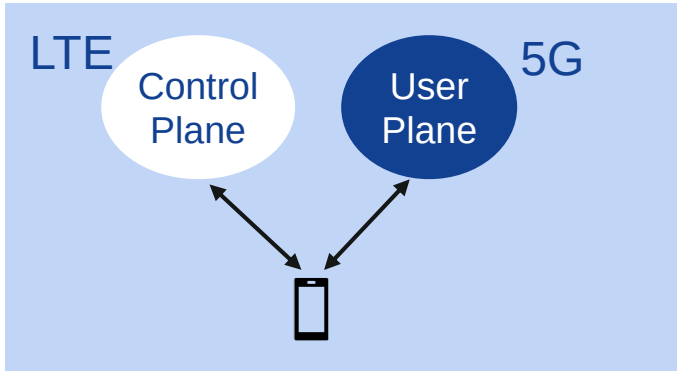
LTE – NR Dual Connectivity

- Stand-alone NR - UE accesses standalone NR carrier and may not be connected to an LTE carrier.
- Non stand-alone NR (dual connectivity of LTE and NR) - UE accesses LTE PCell, then is configured by dual connectivity to also operate on NR
  - UE may be simultaneously connected to LTE and NR, or to LTE for control plane and NR for user plane



Simultaneous connection to LTE and 5G



LTE for control plane and 5G for user plane

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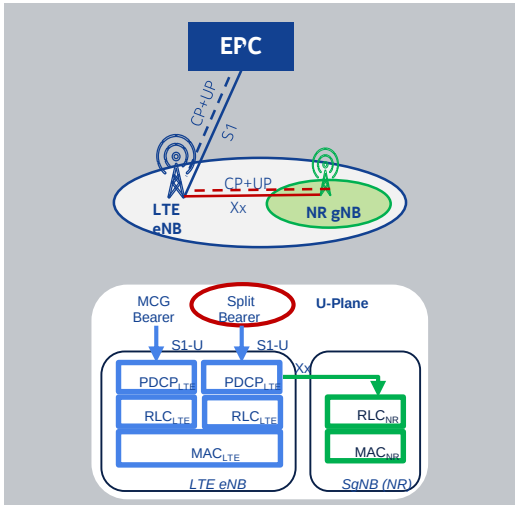
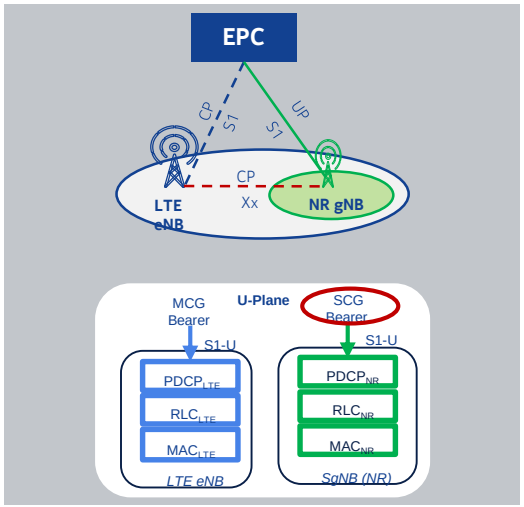
Option 3/3a/3x Overview

Option 3 (MCG Split Bearer)



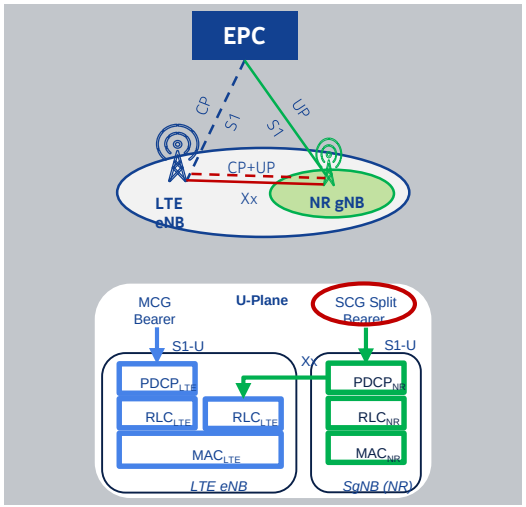
- S1-U anchored at LTE eNB. Mobility signaling between LTE-NR not visible to EPC
- S1-U Split at LTE eNB. Increased load on eNB to process both LTE+5G User Traffic
- Xx interface needs to support CP and 5G user traffic, flow control and latency requirements
- UE mobility interruption (NR to LTE): Impact limited due to split/switched bearer in eNB i.e. traffic sent over LTE when outside NR coverage.

Option 3a (SCG Bearer)



- S1-U anchored at gNB.
- Mobility signaling between LTE-NR visible to EPC due to S1 Path Switch. EPC needs to support E-RAB Modifications.
- S1-U not split and delivered over NR. No additional load to LTE eNB, no flow control needed
- Xx interface used for CP traffic only.
- UE mobility interruption (NR to LTE): Impact due to S1 Path Switch from gNB to eNB

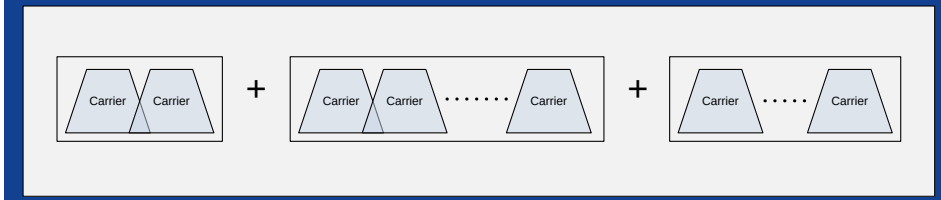
Option 3x (SCG Split Bearer)



- S1-U anchored at gNB.
- Mobility between LTE-NR visible to EPC due to S1 path switch. EPC needs to support E-RAB Modifications.
- S1-U Split at gNB. LTE eNB transmits fraction of user data.
- Xx interface needs to support CP and split user traffic, flow control and strict latency requirements.
- UE mobility interruption (NR to LTE): Impact limited due to split/switched bearer i.e. traffic sent via Xx to LTE when outside NR coverage. S1 path switch leads to impact.

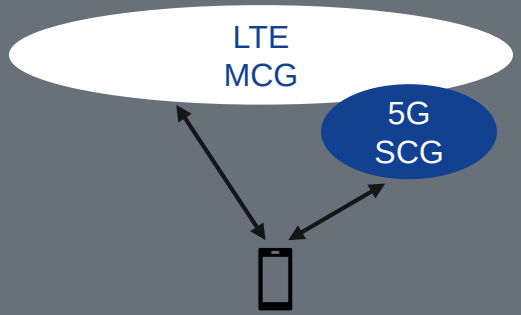
CA/DC for NR Phase 1

Carrier Aggregation for NR Phase 1



- Up to 16 carriers (contiguous and non-contiguous) can be aggregated
- Up to ~1GHz of spectrum can be aggregated
- Carriers can use different numerologies
- Transport block mapping is per carrier
- Cross-carrier scheduling and joint feedback are supported

Dual Connectivity for NR Phase 1



- gNB is not required to broadcast system information other than radio frame timing and SFN
- System information is provided by RRC signaling via LTE master cell

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Conclusions

Carrier Aggregation

- Carrier aggregation (CA) allows a UE to simultaneous transmit and receive data on multiple component carriers from a single eNB
- CA allows network to increase bandwidth and utilize fragmented frequency resources, and provide higher data rates to UE.
- CA allows Licensed Assisted Access deployment using licensed and unlicensed spectrum.
- CA improves peak rates as well as user throughput at low load

Dual Connectivity

- Dual Connectivity (DC) allows a UE to simultaneously transmit and receive data on multiple component carriers from two cell groups via master eNB and secondary eNB
- DC can increase user throughput, provide mobility robustness, and support load-balancing among eNBs

5G NR Phase 1

- CA and DC are enabling technologies for 5G NR
- Up to 16 carriers and approximately 1 GHz can be aggregated for 5G NR Phase 1. Carriers with different numerologies can be aggregated.
- Dual connectivity of LTE and NR allows non-stand alone NR deployment for fast adoption of 5G NR and performance robustness.

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