

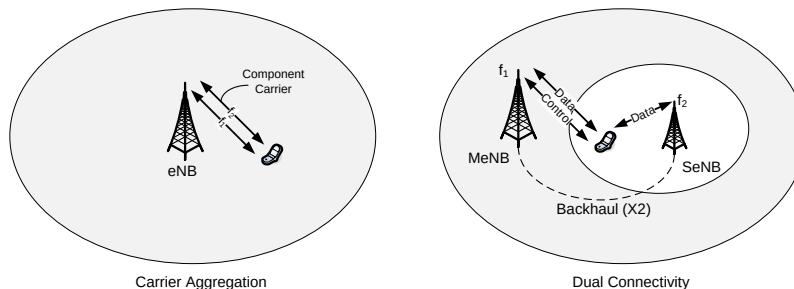
Carrier Aggregation and Dual Connectivity

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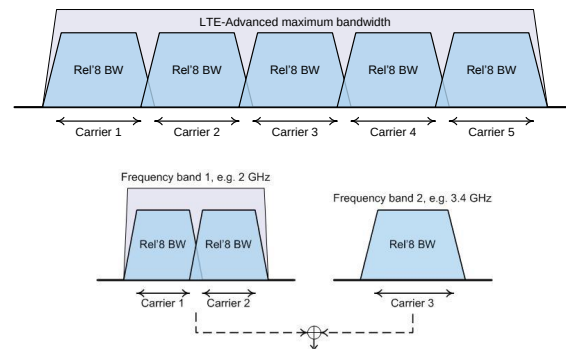
Carrier Aggregation and Dual Connectivity

- Carrier Aggregation (CA) was introduced in 3GPP to allow a UE to simultaneously 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

- 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

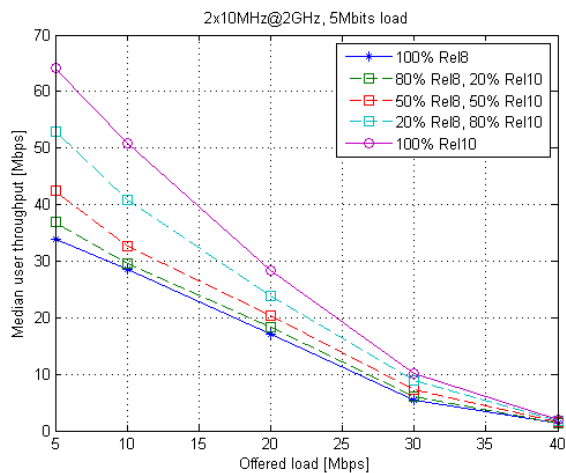


Release	Max No of Carriers	Peak DL Rate	
		2x2 MIMO	8x8 MIMO
LTE-A	5 (up to 100 MHz)	~1 Gbps	~3.9 Gbps
LTE-A Pro	32 (up to 640 MHz)	~6.3 Gbps	~25.1 Gbps

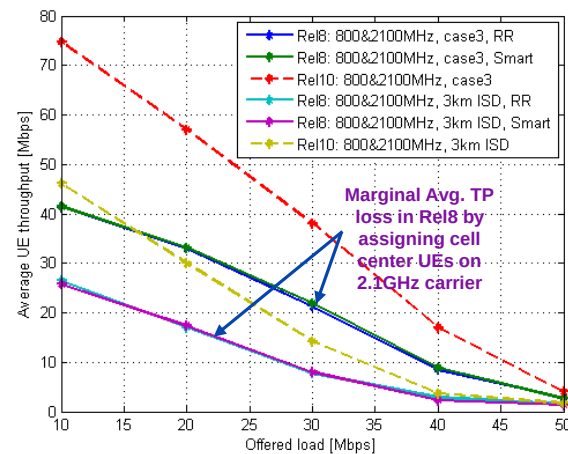
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CA Performance

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



2x10MHz, 2 GHz, median user throughput

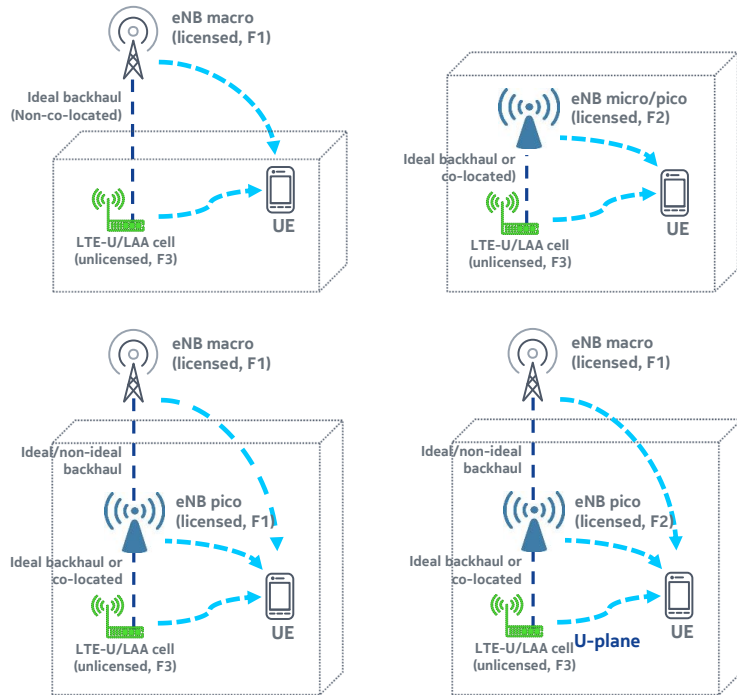


2x10MHz, 2.1 & 0.8 GHz, mean user throughput

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.



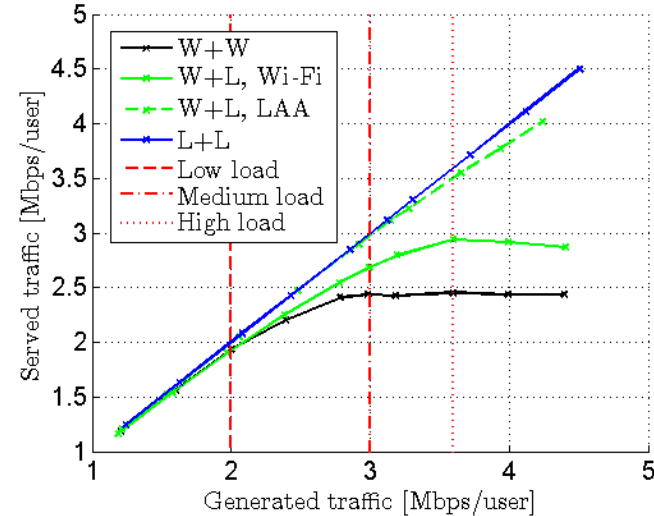
Indoor scenario with DL only traffic: loading

- 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



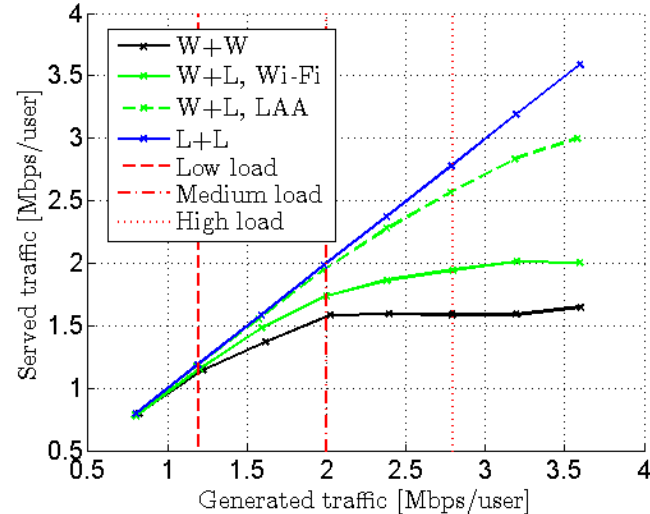
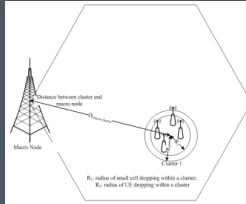
Outdoor scenario with DL only traffic: loading

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.

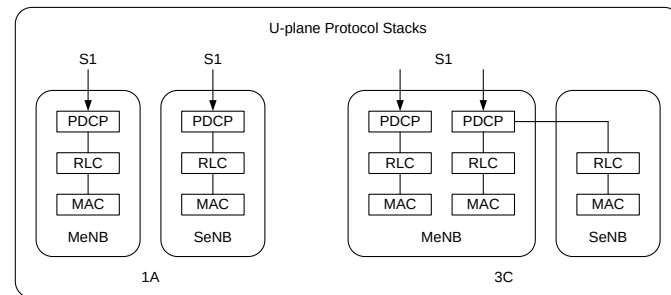
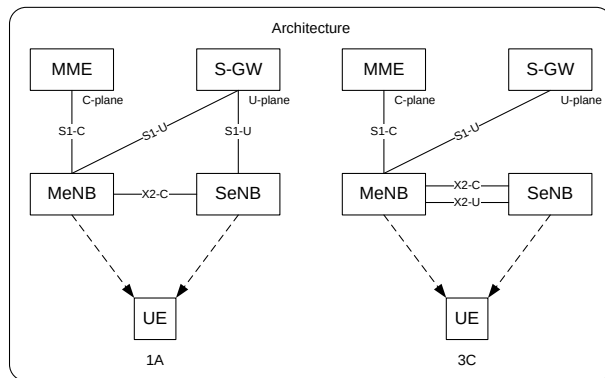
Outdoor scenario:

- 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



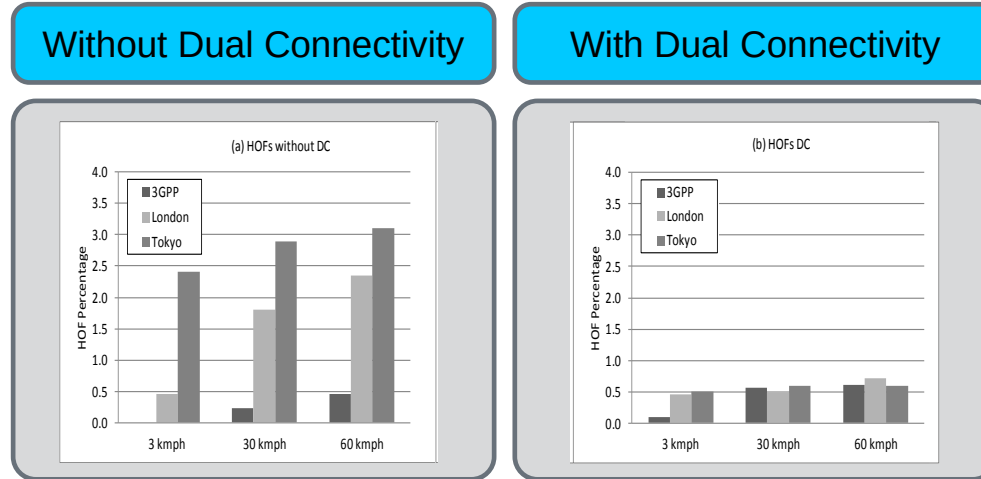
Dual Connectivity Architecture

- 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)



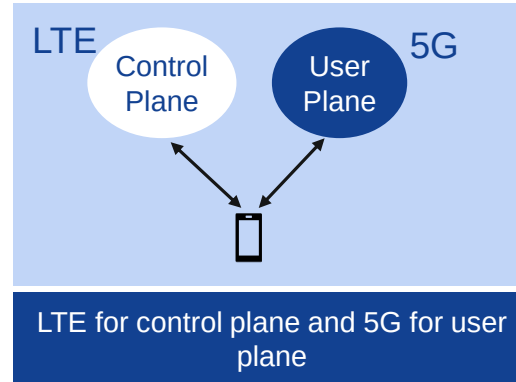
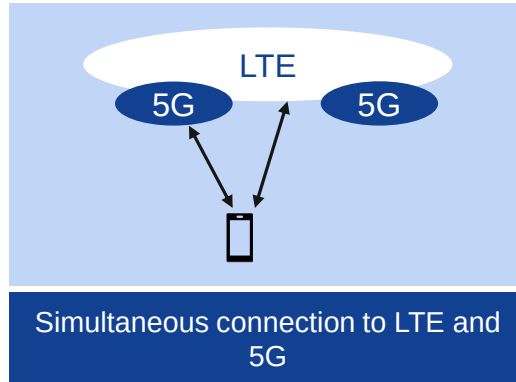
Mobility Robustness with Dual Connectivity

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



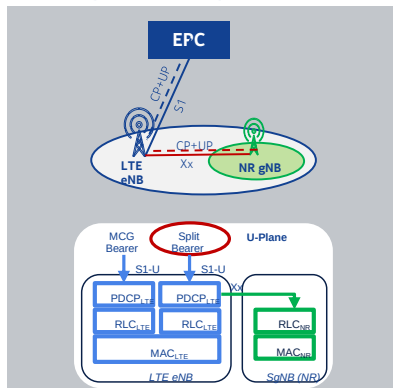
LTE – NR Dual Connectivity

- 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



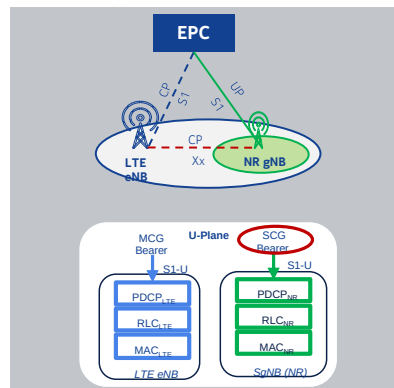
Option 3/3a/3x Overview

Option 3 (MCG Split Bearer)



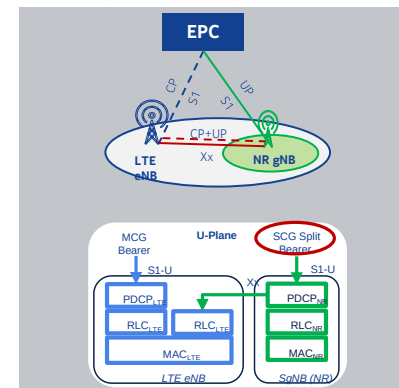
- S1-U anchored at LTE eNB. Mobility signaling between LTE-NR not visible to EPC
- S1-U Split at LTE eNB. Increased load on eNB to process both LTE+5G User Traffic
- Xx interface needs to support CP and 5G user traffic, flow control and latency requirements
- UE mobility interruption (NR to LTE): Impact 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

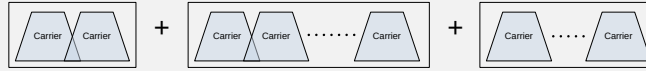
Option 3x (SCG Split Bearer)



- 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.

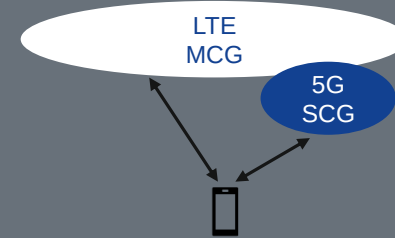
CA/DC for NR Phase 1

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

Conclusions

Carrier Aggregation	Dual Connectivity	5G NR Phase 1
• Carrier aggregation (CA) allows a UE to simultaneously 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 (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	• 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.

The Nokia logo is centered on a solid blue rectangular background. The word "NOKIA" is written in a white, bold, sans-serif typeface.