

Bringing LTE-A to Unlicensed Spectrum: Use Cases, System Performance, Standards, and Coexistence Aspects

- 06-10-2015

Unlicensed Spectrum

Opportunities, Performance, and Options

Performance? Coexistence? Deployment?



Mainstream Approach
Auctions
of Cleared Spectrum

Exclusive Use
Ensures Quality of
Service



Shared Approach
Licensed Shared
Access

Prioritized Use
Less Predictable
Quality of Service



Shared Approach
Unlicensed
LWA/LTE-U/LAA

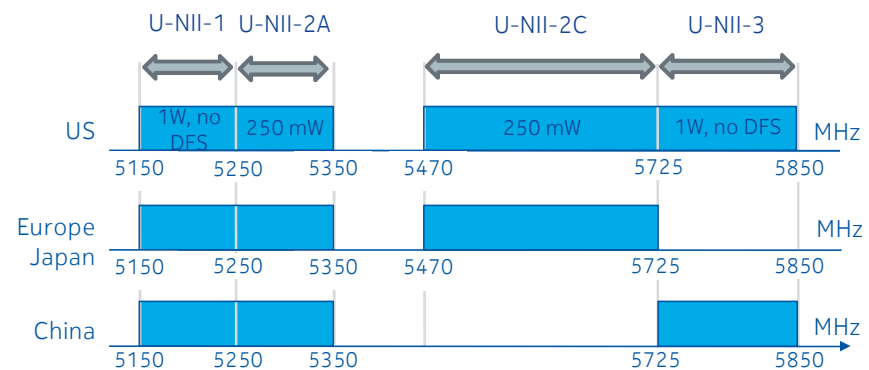
Shared Use
Unpredictable
Quality of Service

Spectrum

Spectrum availability at 5 GHz

- A lot of spectrum available at 5 GHz – as much as **580 MHz**, e.g., in the U.S.
 - For reference, all licensed spectrum together at 700 – 2600 MHz is approximately **670 MHz** (Europe, Asia)
 - 5 GHz band is split into multiple sections with different regulatory requirements
- Globally, all major markets have **300+ MHz spectrum available**

Lots of available spectrum in 5GHz band



Definition of Unlicensed Band Technologies

- LTE-U:
 - Proprietary technology for LTE operating in unlicensed spectrum aggregated with a primary licensed spectrum LTE cell
- Licensed-Assisted Access (LAA):
 - 3GPP standard for LTE operating in unlicensed spectrum aggregated with a primary licensed spectrum LTE cell
- LTE/Wi-Fi Aggregation (LWA):
 - 3GPP standard for radio aggregation of licensed-band LTE and Wi-Fi
- LTE/Wi-Fi Interworking (LWI):
 - 3GPP standard for coordination between licensed-band LTE and Wi-Fi to improve traffic steering between the technologies

High level comparison between LTE-U, LAA, and LWA

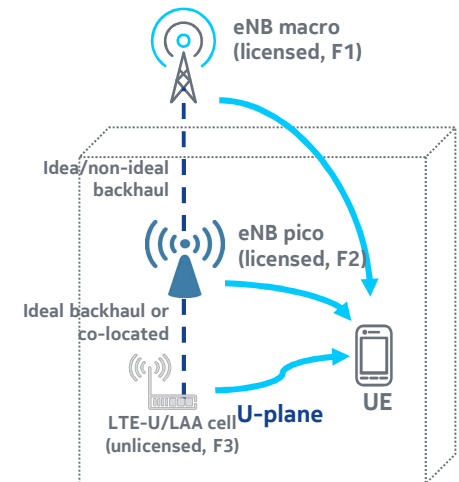
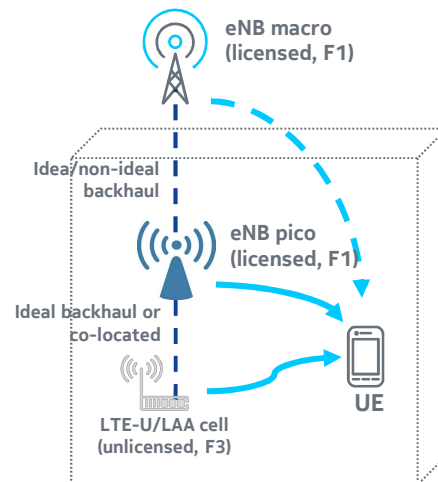
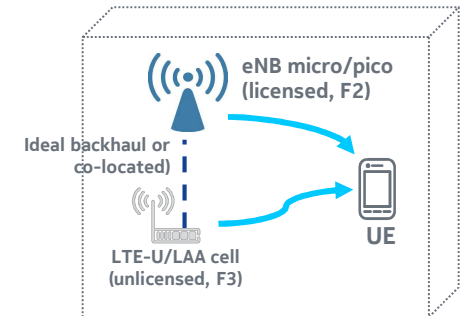
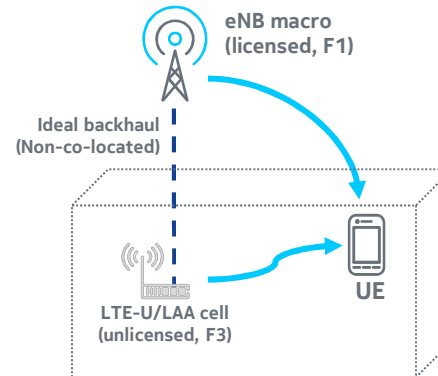
	LTE-U	LAA	LWA
Coexistence	Carrier sensing adaptive transmission (CSAT)	Listen before talk	Listen before talk
Aggregation Level/Bandwidth	MAC-level/ 20-60 MHz	MAC-level/ 20-80 MHz	PDCCP/ 20-160 MHz
Network/UE Support	New APs/eNBs/UEs	New APs/eNBs/UEs	May work with legacy APs/New UEs
Standards/Availability	Proprietary/Available first for specific markets (e.g., US)	3GPP/Specs complete in June 2016	3GPP/Specs complete in Dec. 2015

Use Cases

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.



Deployment Considerations

- Operator's existing deployment: Wi-Fi, small cells, indoor vs. outdoor
 - LTE/Wi-Fi interworking (Rel-12 and Rel-13)
- LTE-U:
 - First technology available
 - Long-term strategy in unlicensed spectrum: Transition to LAA?
- LWA:
 - Appealing with existing Wi-Fi deployment
- LAA:
 - Appealing due to performance, particularly in new deployments

LTE Performance in Unlicensed Bands

LTE Performance Advantages

Advantages brought to unlicensed spectrum

- LTE utilizes time/frequency resources more efficiently:

- LTE: 16.8M subcarriers/sec
- Wi-Fi: 15.6M subcarriers/sec (400ns cyclic prefix)
14.0M subcarriers/sec (800ns cyclic prefix)

8-20%
advantage for
LTE

- Scheduling flexibility

- LTE-U/LAA can transmit to multiple UE's in the same transmit opportunity

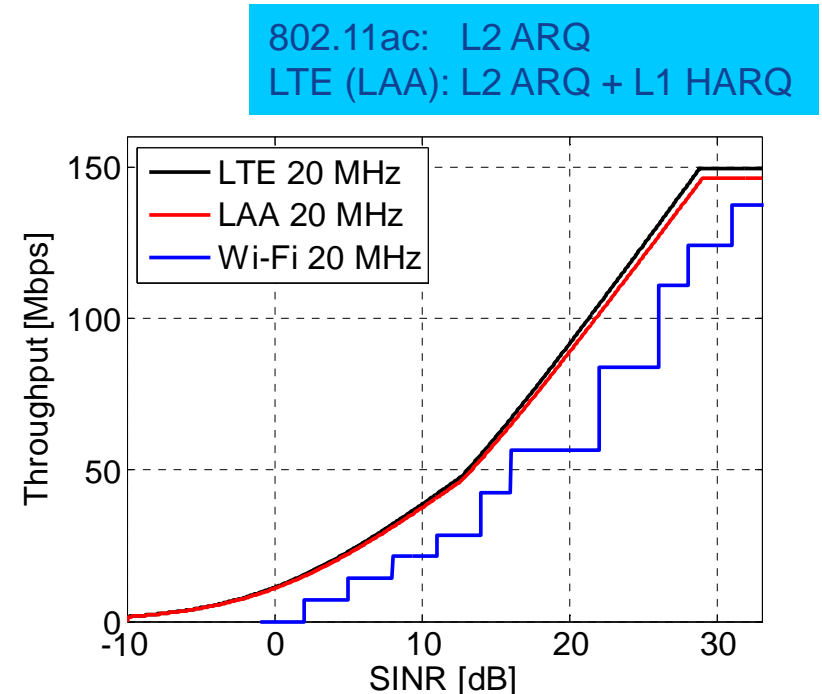
- Robustness to interference

- LTE-U/LAA can support frequency reuse between cells of one operator

LTE Performance Advantages

Spectral Efficiency

- **L1 HARQ** allows operating the physical channel at a higher block error rate at first transmission
 - Energy of erroneous transmissions is not lost but can be combined with successive transmissions
 - Increasing the block error rate at first transmission from 1% to 10-20% can provide a **spectral efficiency gain of ~10-20%**
- **Fast link adaptation** based on channel state information (CSI)
 - Provides an additional **spectral efficiency gain of ~20%**



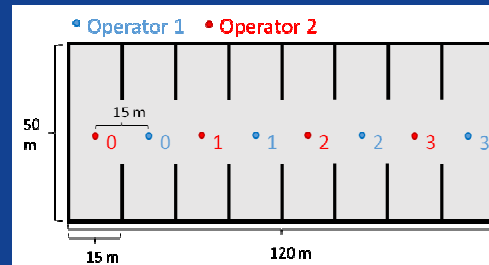
L1 HARQ and fast link adaptation based on CSI can provide a spectral efficiency gain of ~30-40%

System level performance: Indoor deployment Assumptions

RAN1 compatible indoor scenario:

- One or two operators in one hotzone
- 4 APs/eNBs per operator
- 10 terminals/UEs per operator
- 20MHz unlicensed band
- Licensed carrier is not simulated

Traffic model is FTP model 3 with packet size of 0.5Mbytes (DL only)



Category 4 LBT mechanism:

- Based on Load Based Equipment
- Added defer period (DIFs) of 40μs
- Back-off window range increasing exponentially from 15 up to 1023

Wi-Fi assumptions:

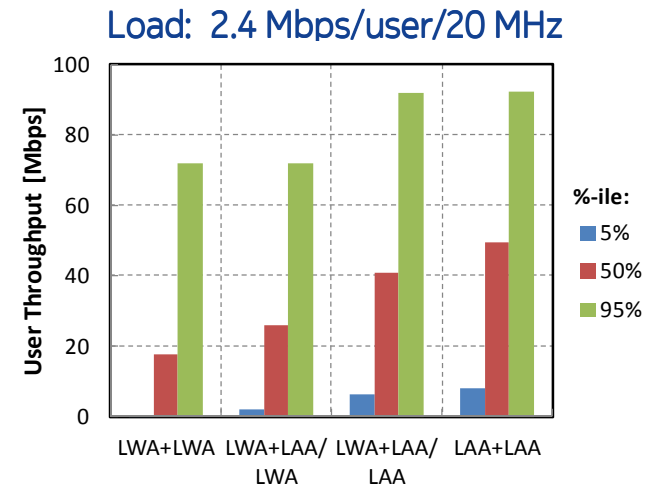
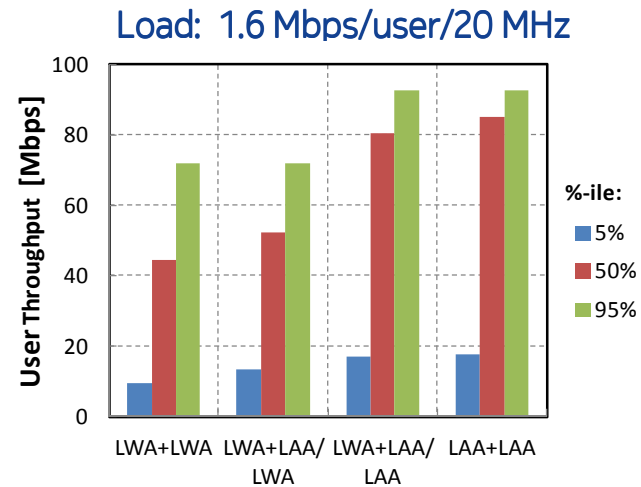
- 802.11ac (long GI = 800 ns)
- CCA threshold -62dBm for energy detection
- CCA threshold -82dBm for preamble detection
- 1x2, i.e. 1 Tx antenna and 2 Rx antennas
- LDPC channel code, 256QAM (maximum coding rate: 3/4)
- Link adaptation based on ACKs
- TxOP up to 4ms

LTE /LAA assumptions:

- 1x2, i.e. 1 Tx antenna and 2 Rx antennas
- Proportional fair scheduling
- Link adaptation based on CSI + OLLA
- CSI measurements only done when eNB is transmitting
- 256QAM (maximum coding rate: 5/6)
- TxOP up to 4ms

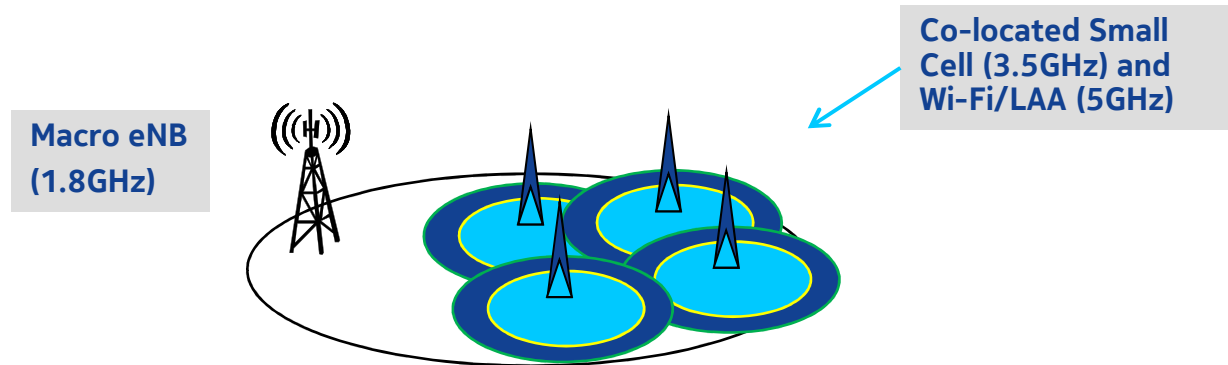
Indoor Results with DL-Only Traffic

Two-operator scenario



- LAA is a fair neighbor, because Wi-Fi performance in the Wi-Fi+LAA scenario is always higher than in the Wi-Fi+Wi-Fi scenario.
- LAA performance is higher than LWA performance across all percentiles and load values.

Outdoor Simulation Scenario



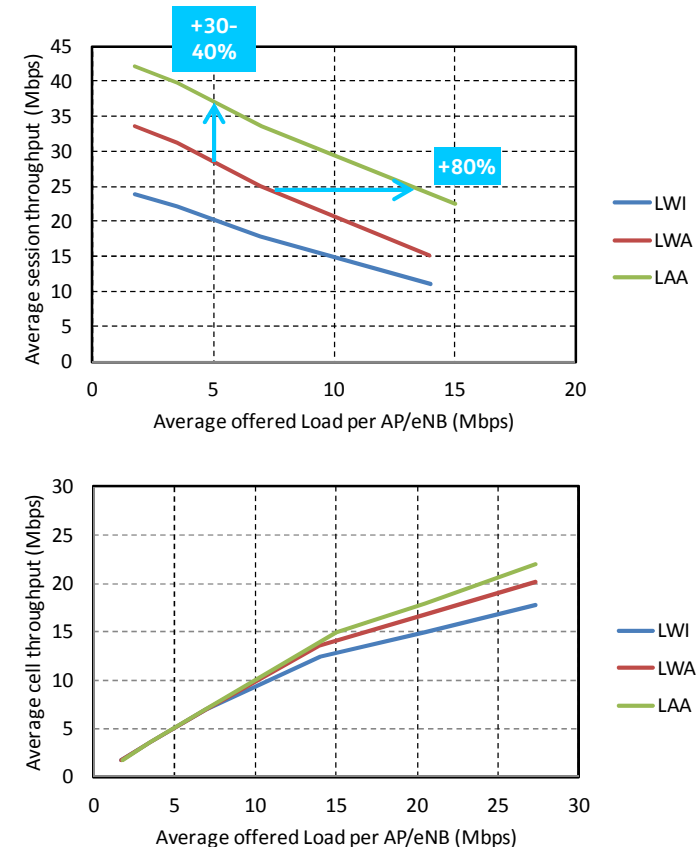
- Hotspot:
 - 4 Small Cells and 4 co-located Wi-Fi/LAA APs per Macro cell
 - 50 m radius for cell placement
 - 40 hotspot UE's
 - 70 m radius for UE placement
- 20 additional UE's per Macro cell
- LTE Macro F1: 1800 MHz (10 MHz bandwidth).
- LTE Small Cell F2: 3500 MHz (10 MHz bandwidth).
- Wi-Fi F3: 5000 MHz (20 MHz bandwidth)
- LAA F3: 5000 MHz (20 MHz bandwidth)

Outdoor Results: Single Operator

4-Cell Hotspot/Macro

- LAA/LWA: UE's aggregated with Wi-Fi above an RSS threshold (−92 dBm)
- LWI: UE's offloaded to Wi-Fi based on Wi-Fi served UE's (up to 4) and RSS threshold (−92 dBm)
- Radio aggregation of licensed and unlicensed spectrum can provide significant improvement over Rel-12 LTE/Wi-Fi interworking
- LAA can provide higher capacity in unlicensed spectrum

Note: Reported throughput is licensed + unlicensed



Summary

Summary

LTE brings performance advantages to unlicensed spectrum

LAA can coexist fairly with Wi-Fi

Operator deployment of LTE in unlicensed spectrum will depend on existing deployments and planned use cases

Both LTE and Wi-Fi are likely to be valuable technologies for unlicensed band deployments

NOKIA