

LTE/WiFi Coexistence Testbed

SDR Application Frameworks

LTE/WIFI Coexistence in ISM-Bands – What It Is About?

- Extremely pushed by Qualcomm since 2014: „Nobody can prevent us from doing that!“
- License Assisted Access: 3GPP flavor
 - Study item finished w/ approved latest Technical Report v1.0.1:
<http://portal.3gpp.org/ngppapp/DownloadTdoc.aspx?contributionId=643760>
 - Work item: http://www.3gpp.org/ftp/meetings_3gpp_sync/ran/Docs/RP-151045.zip
- Proprietary solutions from Qualcomm:
 - LTE-U: <http://lteforum.org/>
 - MuLTEfire from Qualcomm: <https://www.qualcomm.com/news/onq/2015/06/11/introducing-multefire-lte-performance-wi-fi-simplicity>

LAA: Design Targets

- Global solution
 - Ensure region-independent compliance. For e.g. implementing LBT would ensure compliance in regions with regulatory LBT requirements
- Ensure effective + fair co-existence between LAA and Wi-Fi
- Ensure effective + fair co-existence between different LAA operator nodes

Features To Be Implemented for LTE/WIFI Coexistence

1. Discontinuous Transmission

- Flexible subframe-based TX/RX switch on/off
- DL TX Detection,
- AGC control
- Coarse, fine time, freq. synchronization

2. Carrier Sense Mechanisms

- Listen before Talk → LAA
- Carrier Sense Adaptive Transmission → LTE-U

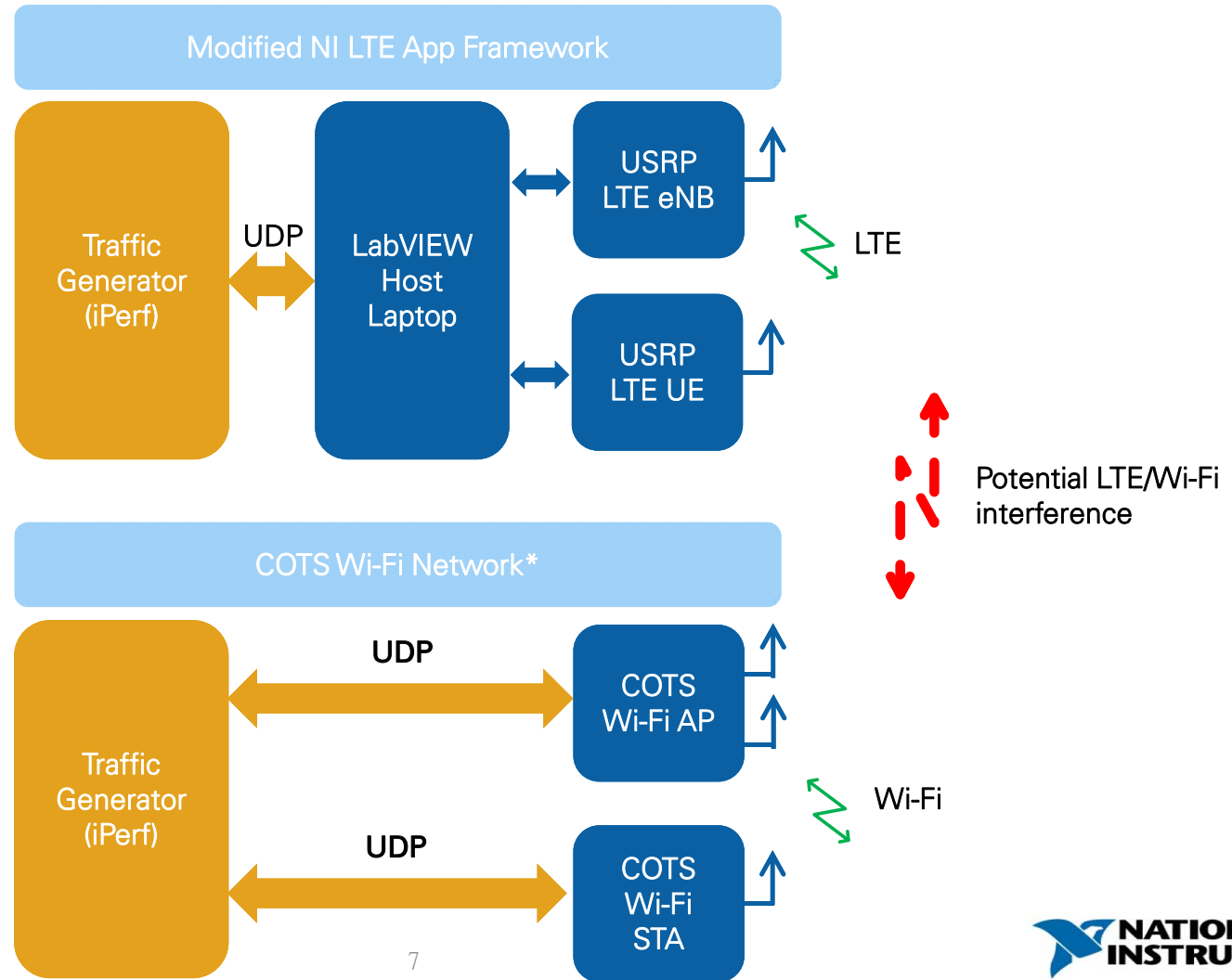
3. Channel Reservation Signal

Why it is beneficial for NI to be active on LTE/WIFI coexistence?

- LTE/WIFI coexistence is extremely controversial between WIFI and cellular communities
- Most of the discussions are based on simulations
- NI as tools provider is neutral, not having stakes neither in WIFI nor in cellular
 - NI provides application example that can be configured towards LAA as well as LTE-U
 - Application example is highly configurable wrt parameters that impact coexistence, such as energy detection threshold, maximum transmission operation time
 - Application example has an open architecture and can be further modified/customized/extended towards more LTE-U/LAA features or more general coexistence research.
 - There will be building blocks that enable customers to prototype their own coexistence solution
- Prototyped solutions yield to real-world-based results
 - Real-world-based measurement results have more weight than simulation-based results
 - Real-world experiments help to get much better understanding how LTE/WIFI coexistence will work
 - Can help to refine simulation models

LTE/Wi-Fi Coexistence Study

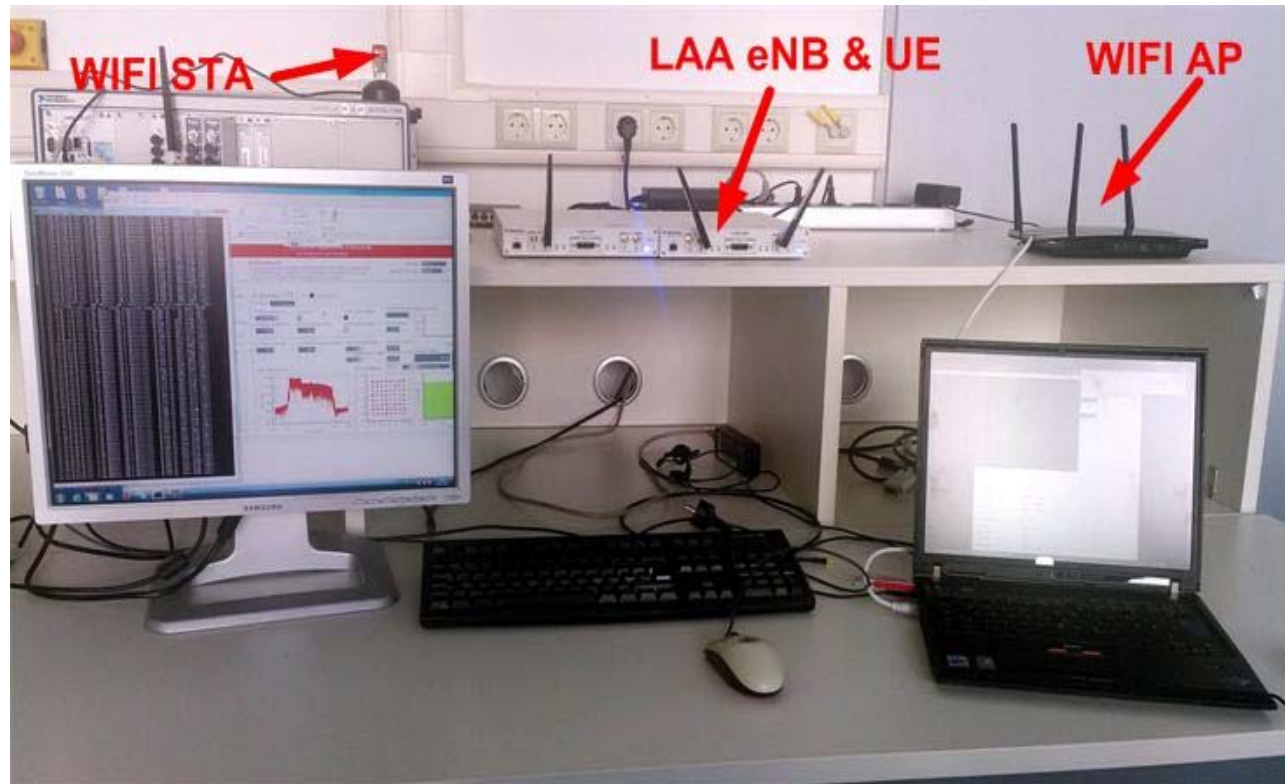
Current LTE/Wi-Fi Coexistence Setup



* Can also use NI 802.11 Application Framework with USRP RIO for emulating Wi-Fi network.

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Current LTE/Wi-Fi Coexistence Setup



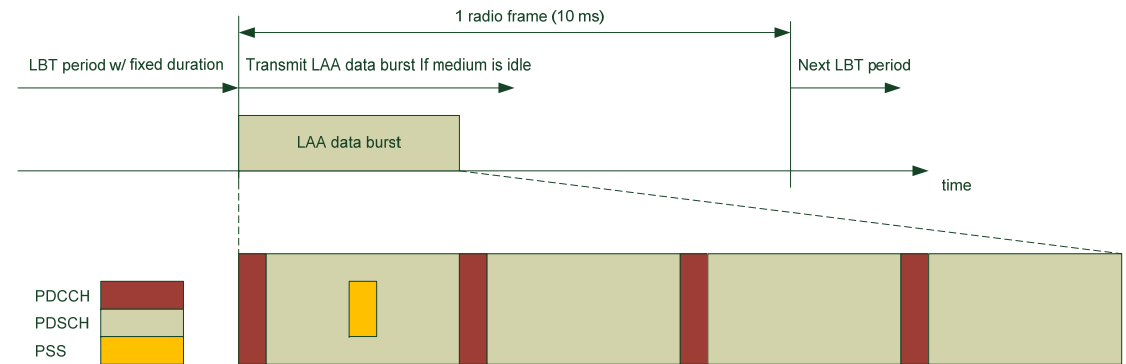
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Current LTE/Wi-Fi Coexistence Setup

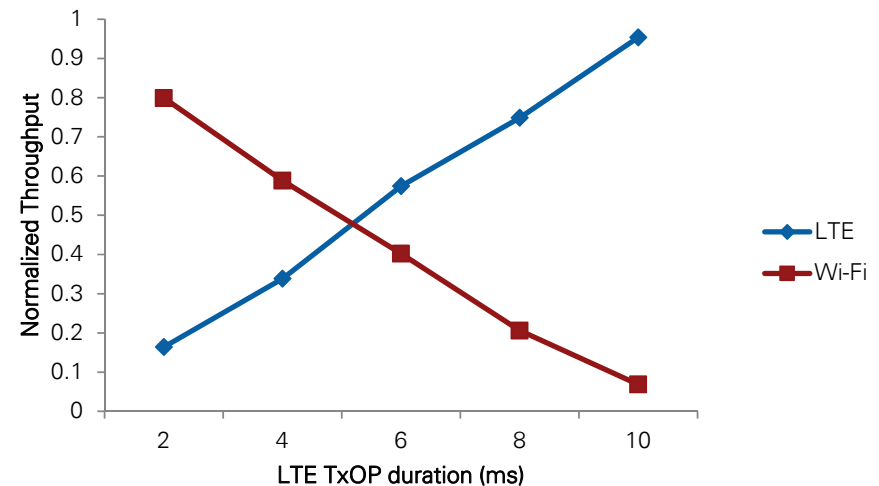
- Hardware
 - Wi-Fi network
 - COTS: 1 AP and 1 STA
 - Or, NI USRP RIO SDR
 - NI USRP RIO SDR for LTE network
 - 1 eNB and 1 UE
- LAA/LTE-U example created using NI SDR software
 - LabVIEW communications system design suite
 - LTE application framework (Host and FPGA)
 - Modified to add LAA/LTE-U functionality
 - 802.11 PHY blocks available from 802.11 application framework

3GPP RAN1 Contribution R1-154740 (Aug 2015)

- Listen before talk:
 - Configurable CCA-ED threshold
 - Cat 2: Configurable duration
- Discontinuous transmission (DTX)
 - FBE (LTE-U): configurable duty cycle
- SISO
- Coexistence metrics
 - Throughput measurements
- Traffic generation
 - iPerf



LAA data burst consisting of n DL subframes of frame structure type 1 with $0 < n < 11$ and $n = 4$ in this figure

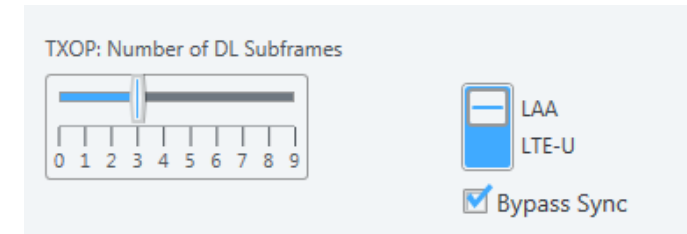


3GPP RAN1 Contribution R1-156622 (Nov 2015)

- Features:
 - Listen before talk: Cat4 with configurable CW and CCA-ED threshold
 - LBE with configurable TXOP
- Setup:
 - Wi-Fi: 802.11ac VHT40, primary carrier: channel 36
 - LAA: channel 38 (non primary carrier of 802.11ac VHT40)
- Evaluation:
 - Wi-Fi baseline performance:
 - Measure throughput of 802.11ac VHT40, primary carrier on channel 36 with a second Wi-Fi 802.11a on channel38. Measure throughput for different RSSI levels
 - Wi-Fi/LAA performance:
 - Repeat the previous measurement but use LAA on channel 38 instead of Wi-Fi 802.11a
 - Measure throughput for different RSSI levels and different LAA CCA-ED thresholds.

Current Features Available

- LAA
 - Listen before talk:
 - Configurable CCA-ED threshold
 - Cat 2: Configurable duration
 - **NEW:** Cat 4: Configurable contention window size (CWS)
 - SISO
 - Discontinuous transmission (DTX)
 - **NEW:** LBE (LAA): Configurable TXOP
- LTE-U
 - FBE (LTE-U): configurable duty cycle
- Coexistence metrics
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Implemented LAA LBT Cat4 Flowchart

- Followed TR 36.889v1.0.1

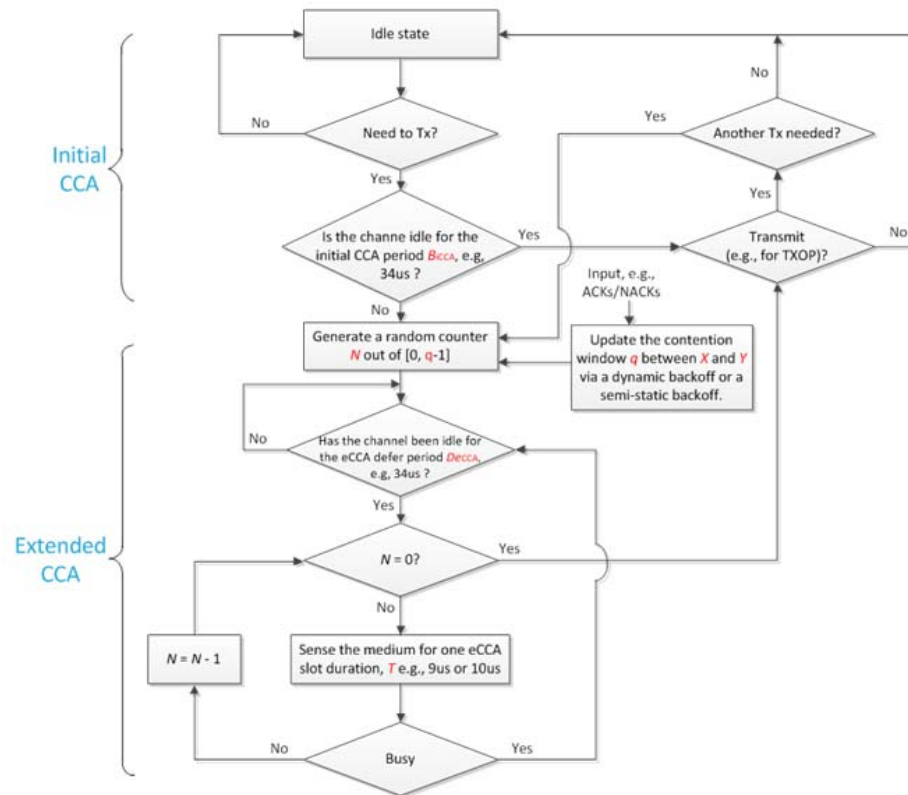
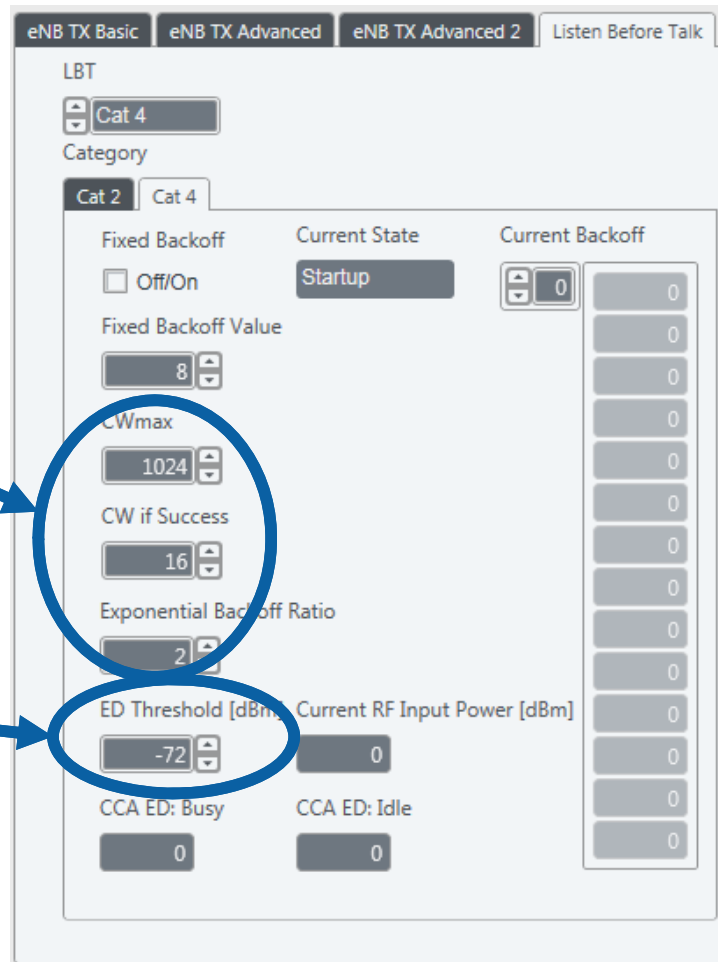


Figure 7.2.1.6-1: Flowchart of DL LAA SCell Cat 4 LBT procedure

- http://www.3gpp.org/ftp/Specs/archive/36_series/36.889/36889-101.zip

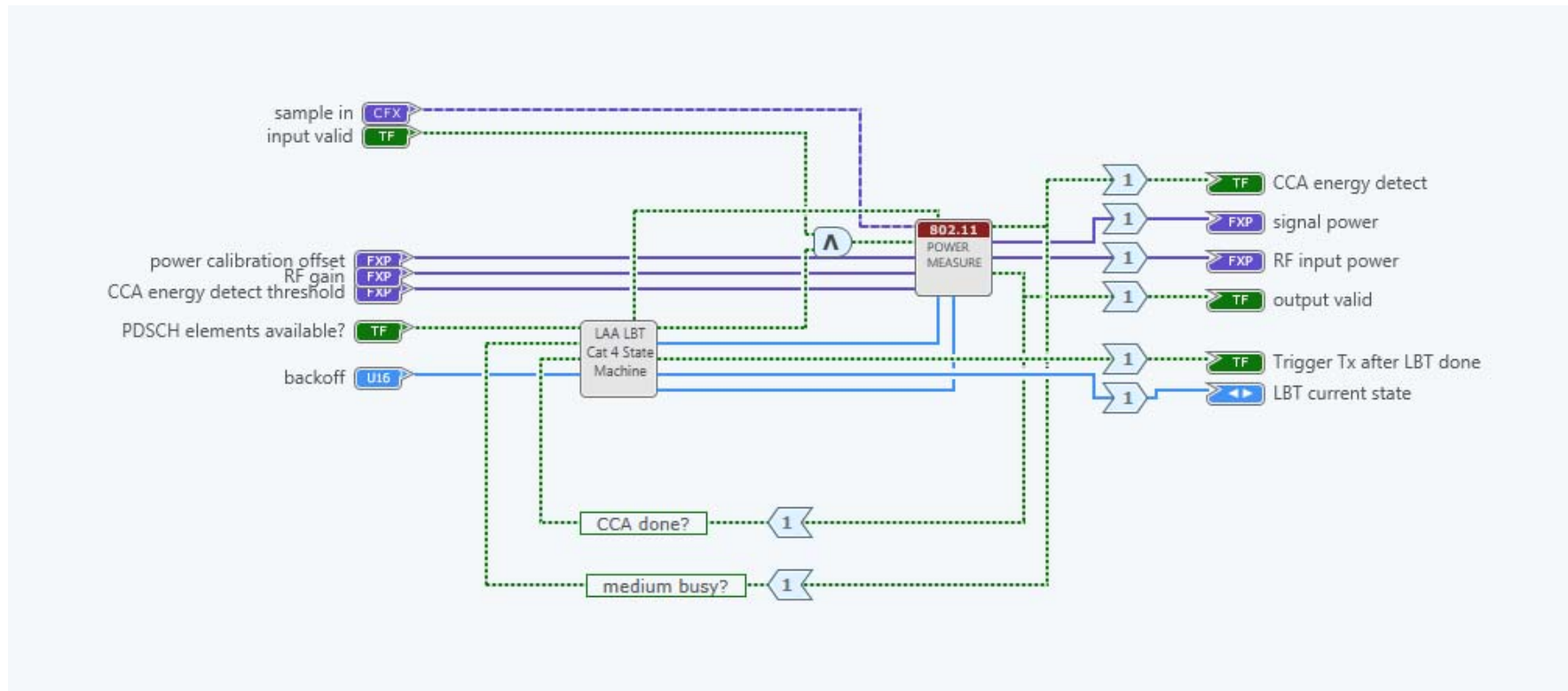
LBT Cat4: Configuration Capabilities



Configurable contention window parameters

Configurable energy detection threshold

LBT Cat4: Top Level

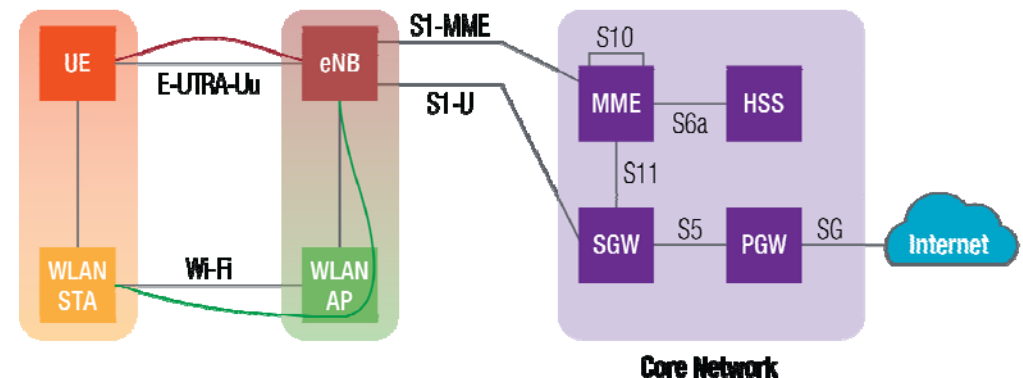


LWA: LTE/Wi-Fi link aggregation on higher layer

- We discussed so far LTE/Wi-Fi coexistence on PHY layer: LAA/LTE-U

- LWA: LTE + Wi-Fi Link Aggregation

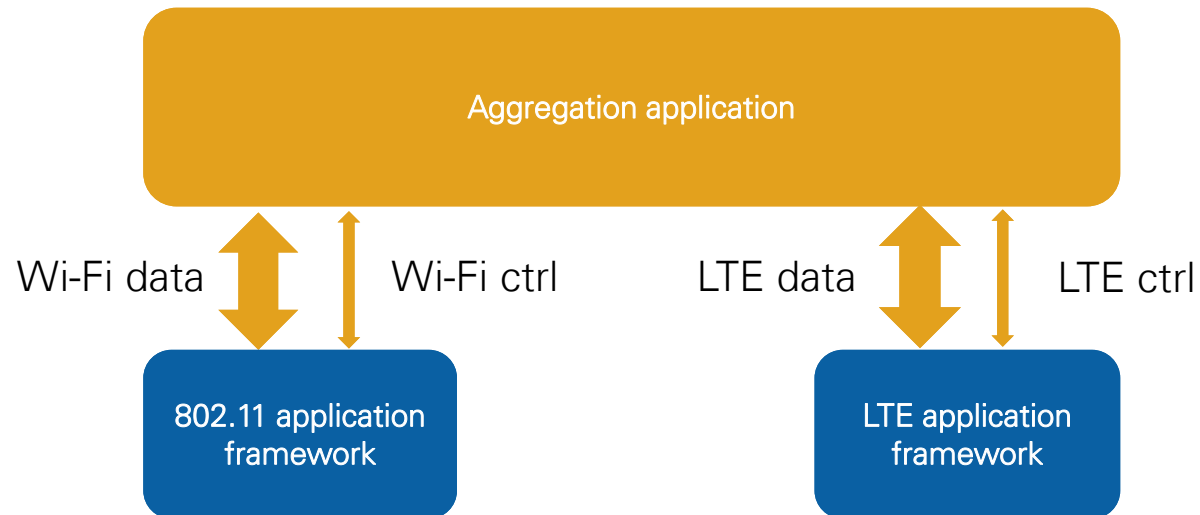
- Aggregation happens on higher layers
- Also part of 3GPP Rel. 13
- Pushed by Ruckus
- Preferred flavor of Wi-Fi community
- Pro from the Wi-Fi standpoint:
 - No need to share physical medium between Wi-Fi and LTE
 - No need to change LTE PHY
- Con from the cellular standpoint:
 - Slow migration path as protocol stack changes on Wi-Fi access points are needed



Source: <http://www.theruckusroom.net/2015/04/getting-engaged-lte-and-wi-fi-falling-in-love.html>

NI Path to LWA

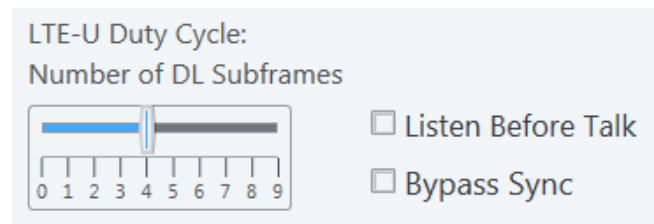
- Take the existing 802.11 and LTE application framework
- Build on top scheduler application for aggregation



- Data: PDCP packets
- Ctrl: Info about link quality such as RSSI, SNR, BLER

LTE-U Status

- Underlying framework for LTE-U is in place
 - Discontinuous transmission
 - Flexible resource mapper
 - Run-time modifiable LTE duty cycle
 - Currently, radio frame-level duty cycling is available



Additional Resources

- LTE/Wi-Fi Coexistence Testbed
 - [Whitepaper](#)
 - [Parts List](#)
- LTE Application Framework [Whitepaper](#)
- 802.11 Application Framework [Whitepaper](#)
- LTE & 802.11 Application Framework 2.0.1 [IPA](#)
- USRP RIO [Product Page](#)