



LTE in Unlicensed Spectrum

Standards and Advanced Technology

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Outline

- Global status on unlicensed spectrum
- Case study on LTE-WLAN co-existence
- Some considerations on 3GPP LTE-U work
- Summary

Unlicensed Spectrum

			2.4GHz	5150-5250	5250-5350	5470-5725	5725-5850
USA	Legacy Systems		Wi-Fi, BT, cordless, ...	Wi-Fi			Wi-Fi
	Rules	Protecting incumbent	N/A	N/A*	DFS/TPC		No DFS
		Co-exist with Legacy	FCC Part 15.247, 15.401 -407, max Tx power and emission mask				
EU	Legacy Systems		Wi-Fi, BT, cordless, ...	Wi-Fi			In planning, Non-specific SRD may operate at 25mW eirp
	Rules	Protecting incumbent	N/A	Indoor only	Indoor only for 5250-5350, DFS/TPC		
		Co-exist with Legacy	LBT, max Tx power and emission mask				
China	Legacy Systems		Wi-Fi, BT, cordless, ...	Wi-Fi		TBD	Lightly licensed, Wi-Fi, P2MP
	Rules	Protecting incumbent	N/A	Indoor only	Indoor only, DFS/TPC		N/A
		Co-exist with Legacy		Max Tx power and emission mask			Max EIRP: 25mW, 2W
Japan	Legacy Systems		Wi-Fi, BT, cordless, ...	Wi-Fi		Wi-Fi	DSRC (5770-5850), ISM equipment (no radio com)
	Rules	Protecting incumbent	N/A	Indoor only	Indoor only with DFS/TPC	DFS/TPC	N/A
		Co-exist with Legacy	LBT, Max. conducted power and antenna gain, emission mask defined for each system				ISM, DSRC: Max. conducted power and EIRP, emission mask
Korea	Legacy Systems		Wi-Fi, BT, cordless, ...	Wi-Fi		Wi-Fi (5470-5650), broadcasting relay system(5650-5725)	Wi-Fi (5725-5825), DSRC(5835-5855)
	Rules	Protecting incumbent	N/A	Indoor only	DFS/TPC	DFS/TPC (5470-5650)	N/A
		Co-exist with Legacy	Max. conducted power and antenna gain, spurious emission defined for each system				

* Recent rule changing in US: indoor restriction is removed

* 3.5GHz in US is under the discussion to be allocated as "lightly-licensed" spectrum

Observations

- 2.4GHz and 5150-5350MHz are available globally, but with many issues not suitable for LTE small cell deployment;
 - In US, FCC recently removed indoor-only restriction in 5150-5250MHz. The max permitted Tx power has been increased to 1W;
- 5470-5725 are available in US, EU, Japan and Korea. This band has DFS/TPC mandate.
- 5725-5850 are available in US and Korea with no DFS/TPC mandate.
- Prefer the global solutions to satisfy the co-existence and regulatory requirements in the potential LTE-U bands.

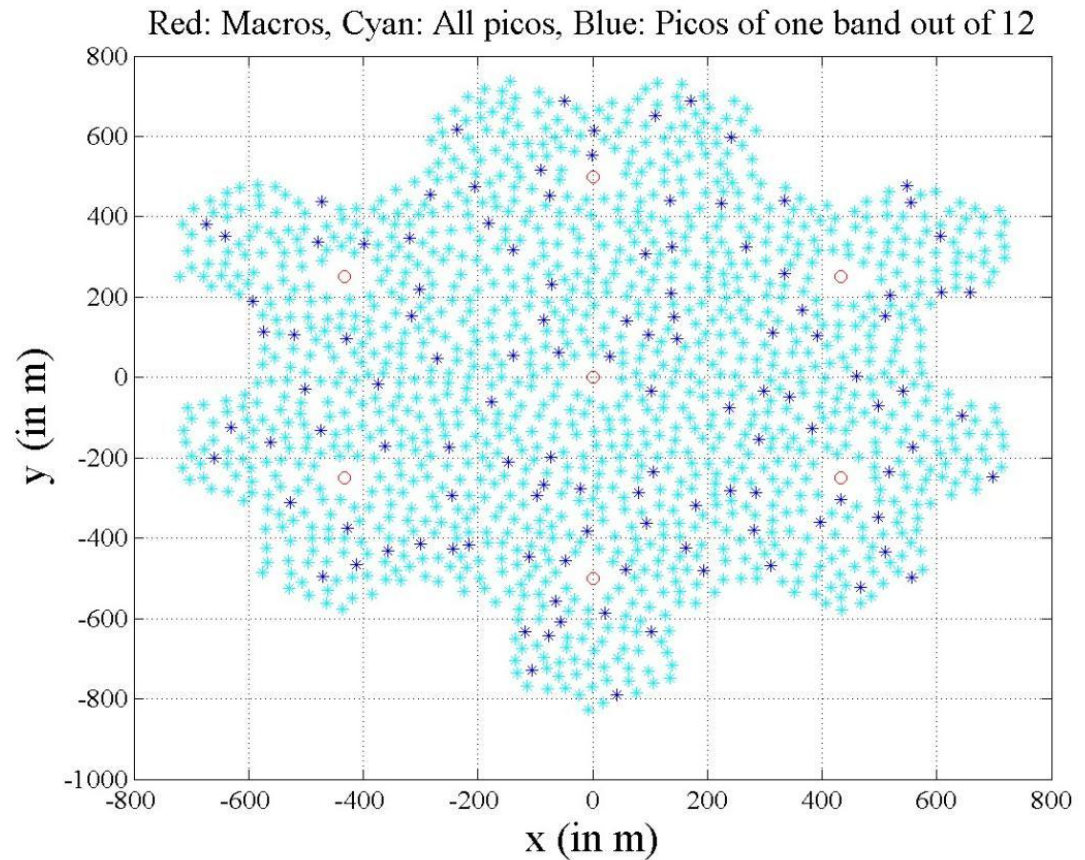
Case Study on LTE-WLAN Co-Existence

LTE-WLAN Co-existence: Case 1

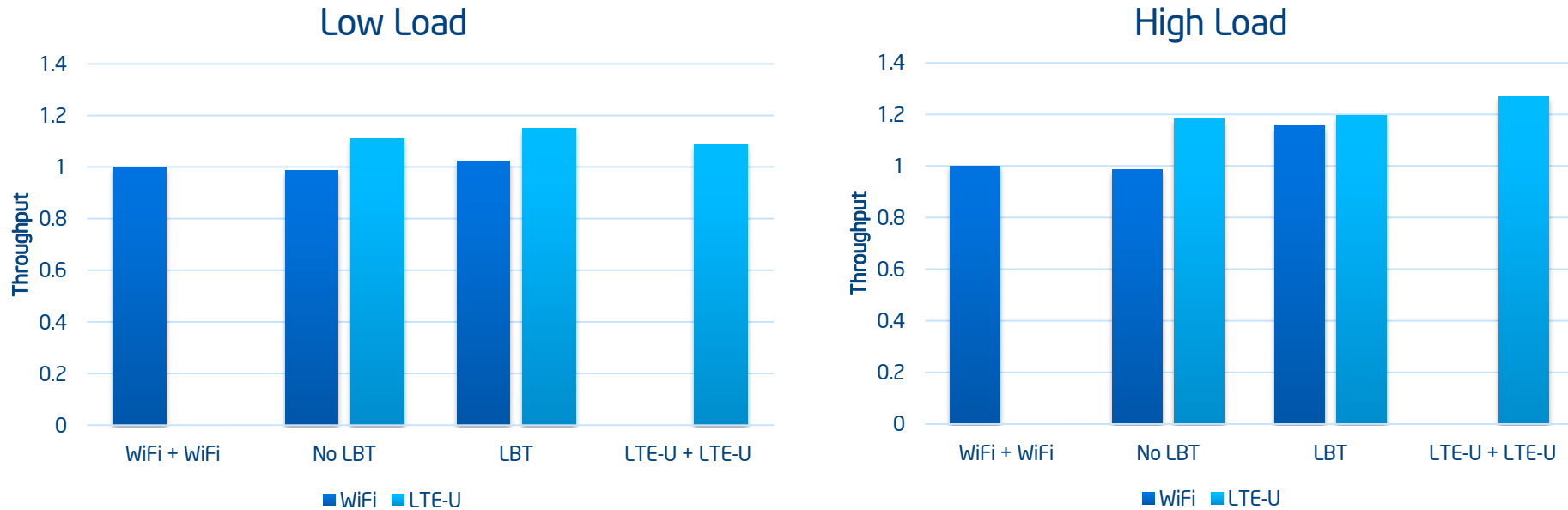
20dBm DL Tx power at LTE and WLAN

Simulation assumptions

- 2 operators, downlink-only traffic on unlicensed SC layer,
- FTP model 2 traffic. Low load: 0.2 MB file, 2 files/s. High load: 1 MB file, 10 files/s
- 64 LPNs and 200 UEs dropped uniformly per macro cell area (ISD=500m)
- 3ms transmission duration for LTE-U, 3ms TXOP for WLAN
- 1, 3, 6, 12 bands (each with 20 MHz bandwidth)



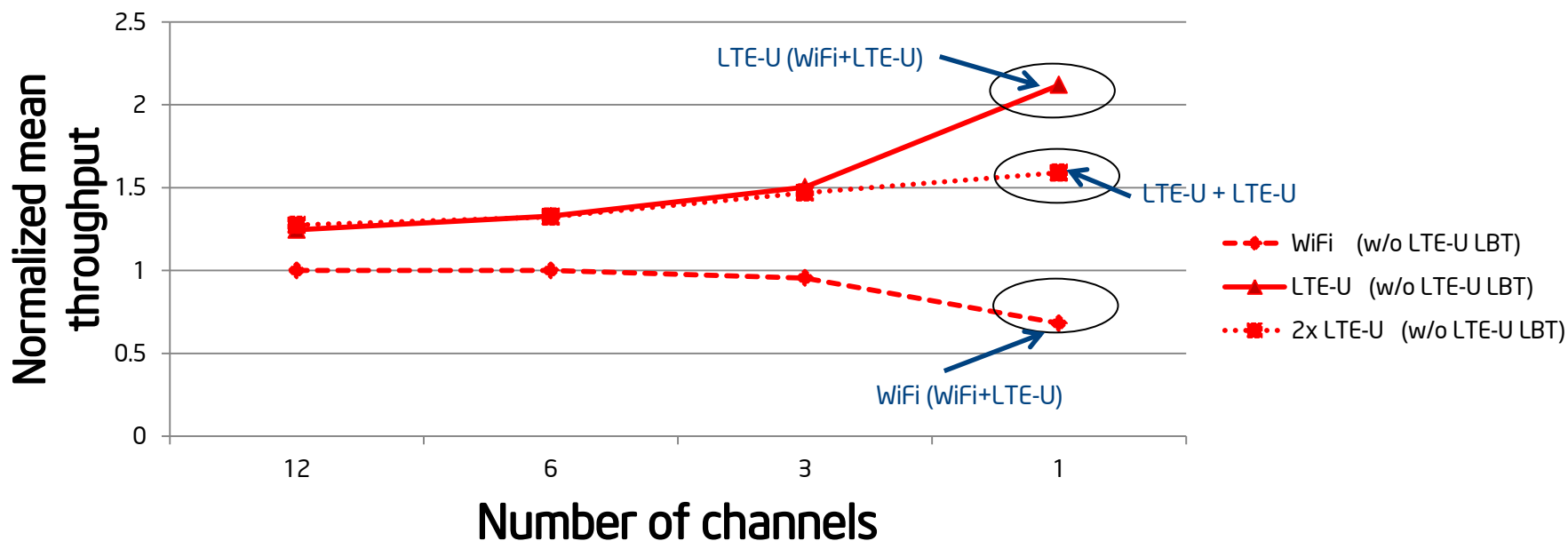
LTE-WLAN Co-existence: Case 1 (12-Channel)



- WLAN performance degrades slightly when co-existing with LTE
- LBT improves the performance of both LTE and WLAN

LTE-WLAN Co-existence: Case 1

Impact analysis of channel availability



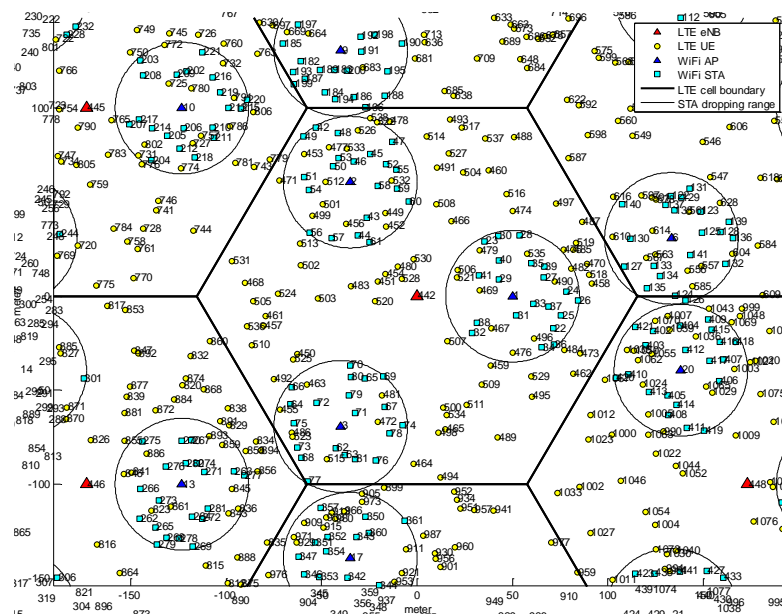
- Results for 100% resource utilization and normalized to WLAN+WLAN performance
- As channel availability decreases:
 - WLAN degradation due to coexistence with LTE-U becomes more significant
 - Performance gain of LTE-U over WLAN increases

LTE-WLAN Co-existence: Case 2

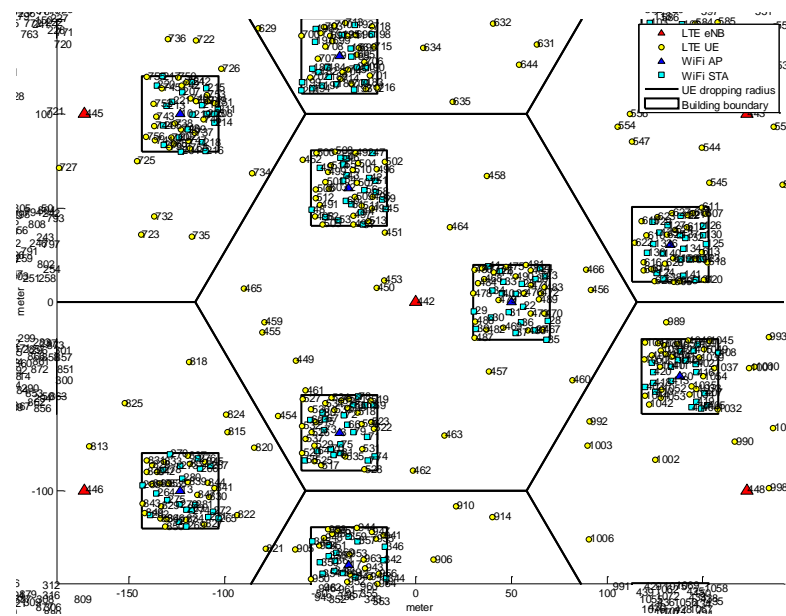
30dBm DL Tx power at LTE, 20dBm DL Tx power at WLAN

Simulation assumptions

- LTE ISD: 200 m; WLAN dropping radius: 35 m; 3APs per macro eNB
- 3GPP FTP model 1 with 0.5 MB file; LTE DL only, WLAN equal traffic splitting DL & UL
- 90 LTE UEs per eNB and 20 STAs per AP
- 3ms transmission duration for LTE-U, 3ms TXOP for WLAN
- 12 bands (each with 20 MHz bandwidth)

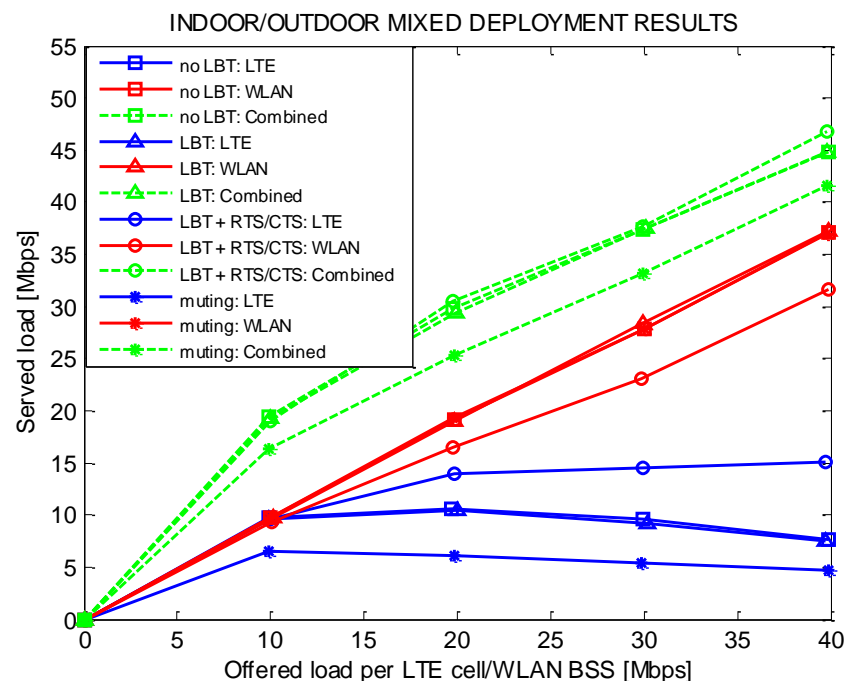
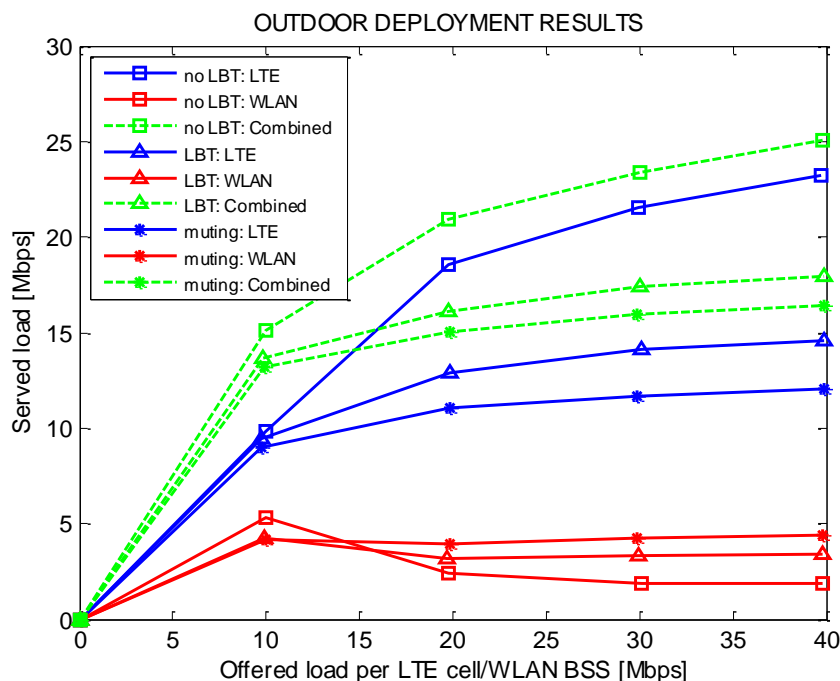


[Outdoor]



[Indoor/outdoor mixed]

LTE-WLAN Co-existence: Case 2



- In the outdoor deployment setup, LTE operation can significantly degrade WLAN performance;
 - LBT exhibits a better balancing than static muting (50% duty cycle) between improving fairness and maximizing overall spectrum efficiency;
- In the indoor/outdoor deployment, due to hidden node effect, UE performing RTS/CTS-like operation is required to achieve a good balance between fairness and spectrum efficiency;

Some Considerations on 3GPP LTE-U Work

LTE-U and WLAN Deployment

- LTE-U:
 - Operator deployed;
 - Aggregated with licensed spectrum (DL only → DL-UL):
 - Signaling and critical data to be carried over the licensed spectrum;
 - Common channels to be sent over the unlicensed spectrum to support synchronization, RRM measurement, etc.;
 - Multiple operator-deployments in the same geographic area on the same spectrum;
- WLAN:
 - Diverse deployment:
 - Carrier-deployed public Wi-Fi, Residential Wi-Fi, Small business Wi-Fi, ...
 - Diverse services:
 - Web browsing, streaming, VoIP, Video conferencing, etc

Co-existence Evaluation Methodology

- LTE-WLAN co-existence scenarios:
 - Outdoor LTE-U eNBs with outdoor/indoor UEs, Indoor WLAN APs with indoor STAs
 - Outdoor LTE-U eNBs with outdoor UEs, Outdoor WLAN APs with outdoor STAs
 - Indoor LTE-U eNBs with indoor UEs, Indoor WLAN APs with indoor STAs
 - Outdoor LTE-U eNBs with outdoor/indoor UEs, Indoor WLAN APs with outdoor/indoor STAs
- Traffic model:
 - Non-full-buffer FTP
 - VoIP
- Performance metrics:
 - Throughput
 - Latency
 - Synchronization and measurement robustness

Summary

- Global solutions to satisfy the co-existence and regulatory requirements in the potential LTE-U bands are preferred;
- The co-existence study showed;
 - LTE-U outperforms WLAN in dense deployment ranging from 10~60% depending on the traffic load and channel availability;
 - LTE significantly degrades WLAN when the shared channel becomes congested;. LBT shows potential to ensure the fairness;
 - Furthermore, hidden-node issue needs to be addressed;
 - In DL only operation, LTE-U DL is vulnerable to near-by WLAN transmission;
- Co-existence scenarios and performance metrics to be considered in the evaluation methodology have been proposed;
- Regarding LTE-U work in 3GPP:
 - RAN1-led SI may start after Rel-12 completion;
 - RAN4-led WI should not start until the co-existence study is completed in RAN-1 led SI;

