WHITE PAPER

LTE-WLAN Aggregation (LWA): Benefits and Deployment Considerations

Next Generation and Standards Group

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Abstract

Cellular networks have evolved from delivering robust voice services with 1st and 2nd generation standards towards generations of standards that enable data-centric networks and the proliferation of Smartphones with Wi-Fi and 3G/LTE capabilities. The resulting surge in data traffic volumes has led operators to recognize the opportunity offered by both Wi-Fi technology and unlicensed spectrum for traffic offload.

In response to operator need for integrated Wi-Fi offloading technologies in their networks, the 3rd Generation Partnership Project (3GPP) has defined various methods of LTE-WLAN interworking ranging from Non-Seamless WLAN Offload (NSWO) and loosely coupled methods such as S2b (later on enhanced with radio layer interworking capabilities), to LTE-WLAN Radio Level Integration, a more advanced RAN anchored solution with IPsec Tunnel (LWIP), to LTE-WLAN Aggregation (LWA), which allows operators to seamlessly integrate WLAN as a "new Radio Access Network (RAN)", into their network.

As 3GPP and the industry work towards determining solutions for aggregation of licensed and unlicensed spectrum, two technologies have emerged using this principle: Licensed Assisted Access (LAA) which uses LTE in unlicensed spectrum in place of Wi-Fi and LTE-Wireless LAN Aggregation (LWA) which Wi-Fi together with LTE. While both provide similar performance improvements compared to existing interworking solutions, LWA deployment considerations will be the focus of this paper as well as a discussion of the ways operators can leverage their existing investments in WLAN infrastructure to roll out LWA without changes to already deployed WLAN Access Points (APs).

This paper, describes LTE-WLAN Aggregation (LWA) architecture and operation, and demonstrates that LWA can provide comparable performance to other technology innovations for use in the unlicensed bands. Special focus is given to LWA deployment considerations to address operator desire to deploy the technology with minimum impact to the legacy WLAN and LTE infrastructure.

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LWA Overview

LTE-WLAN Aggregation (LWA) is a feature of 3GPP Release-13 which allows a mobile device to be configured by the network so that it utilizes its LTE and Wi-Fi links simultaneously. Unlike other LTE/WLAN interworking methods (e.g. S2b and LWIP), which also allow using LTE and WLAN simultaneously, LWA has the capability to split a single bearer (or a single IP flow) at sub-bearer granularity while accounting for channel conditions. This capability allows all applications (e.g. video streaming and file download) to use both LTE and WLAN links simultaneously without any application-level enhancements, thus providing significant performance gains.

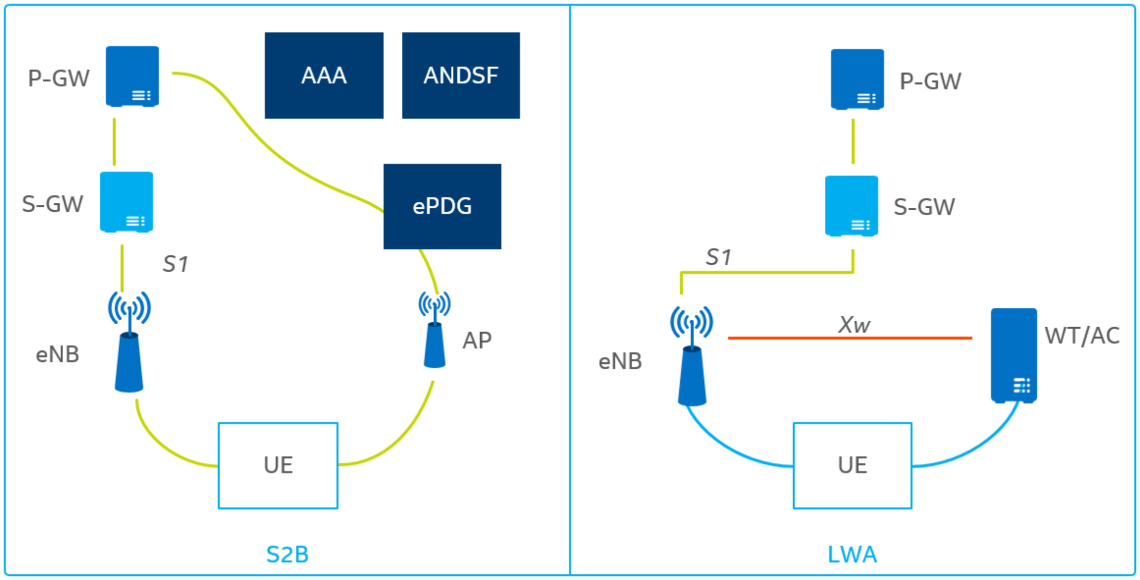
As illustrated in more detail in the following sections, the benefit of LWA for a user is that it provides improved quality of service by increasing peak and average throughput and makes WLAN usage seamless and transparent.

With LWA, the user equipment (UE) will automatically utilize operator deployed WLAN without user intervention. If a user wishes to use a non LWA enabled network, he or she may connect to the desired network even while an LWA session is ongoing. For cases when the device does not support a simultaneous connection to two different Wi-Fi Access Points, it will disassociate from the LWA-enabled WLAN AP and connect to the user selected WLAN network. This is done while any existing sessions continue, uninterrupted, over the LTE bearer.

As we showed in detail below, the benefit of LWA for an operator includes increases in system capacity, the ability to maximize the number of users who can be served without making major upgrades to the network, and the simplification of WLAN operation within the cellular network.

With legacy LTE-WLAN interworking technologies, such as S2b, the operator has to deploy and maintain two separate networks - one for licensed spectrum and one for unlicensed spectrum. LWA allows the operator to integrate WLAN at the radio access network (RAN) level which can eliminate costly WLAN-specific core network (CN) nodes (e.g. ePDG) thus reducing core network (CN) signaling and making WLAN deployment easier and cheaper to maintain. This concept is illustrated in Figure 1 below.

FIGURE 1. S2B (LTE/WLAN INTERWORKING VIA UNTRUSTED WLAN ACCESS) AND LWA (LTE-WLAN AGGREGATION) NETWORK ARCHITECTURE

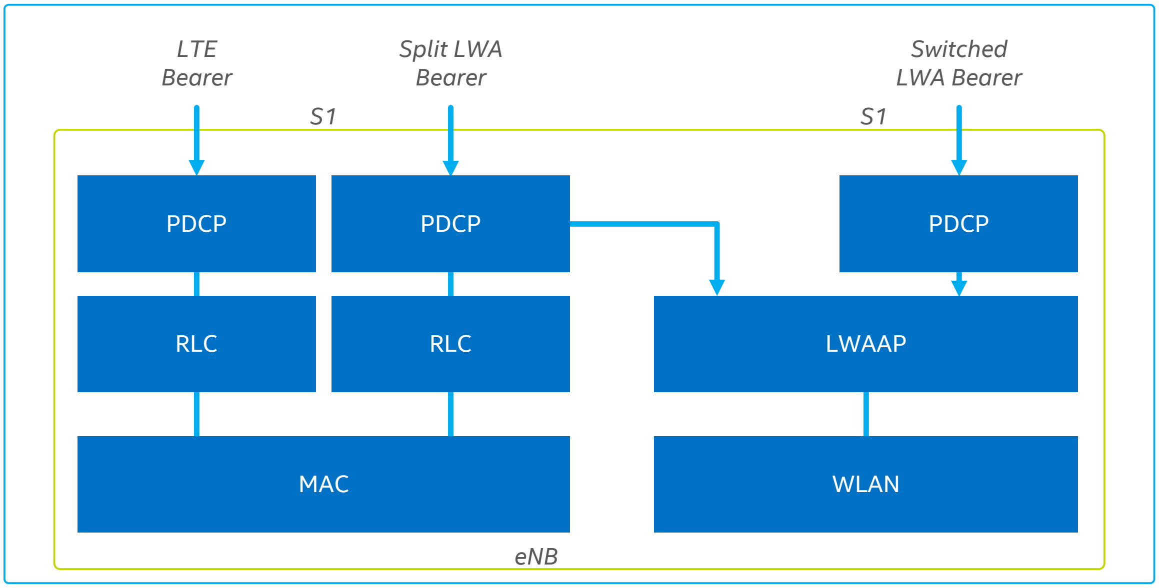


With LWA, the eNB being both control and user plane anchor, effectively takes on the roles of ANDSF and ePDG, as we showed below. In addition, LWA also allows the operator to deploy WLAN with a sufficient level of network control to ensure efficient network resources usage of both LTE and WLAN[1].

User Plane Architecture

LWA design primarily follows LTE Dual Connectivity (DC) architecture[2] as defined in 3GPP Release 12, which allows a UE to connect to multiple base stations simultaneously. This simplifies network and UE implementation, as parts of the DC functionality can be re-used for LWA. In the user plane, LTE and WLAN are aggregated at the Packet Data Convergence Protocol (PDCP) level, as illustrated in Figure 2.

FIGURE 2. LWA (LTE-WLAN AGGREGATION) USER PLANE ARCHITECTURE



In the downlink, the eNB may schedule PDCP PDUs of the same bearer to be delivered to the UE either via LTE or WLAN. In order to perform efficient scheduling and to assign packets to LTE and WLAN links in the most efficient manner, the eNB can receive radio information about both links, including flow control indication.

In order to avoid changes to the WLAN MAC, 3GPP has defined a new EtherType (allocated by IEEE RAC for LWA)[3] and an LWA Adaptation Protocol (LWAAP)[4], which are transparent to WLAN. The EtherType allows the UE to differentiate between LWA and non-LWA packets and the LWAAP protocol carries bearer identification, which allows to offload multiple bearers with LWA.

The PDCP layer in the UE performs re-ordering (in a similar way to DC), which allows packet-by-packet scheduling on both LTE and WLAN links.

Control Plane Architecture

When considering the LWA control plane functionality, Evolved Node B (eNB) is responsible for LWA activation, de-activation and the decision as to which bearers are offloaded to the WLAN.

As part of Release 13, 3GPP has extended the LTE measurement framework to support WLAN measurements which are used by the eNB to control LWA operation and scheduling. New measurement events have been defined to control LWA activation, deactivation and mobility[5].

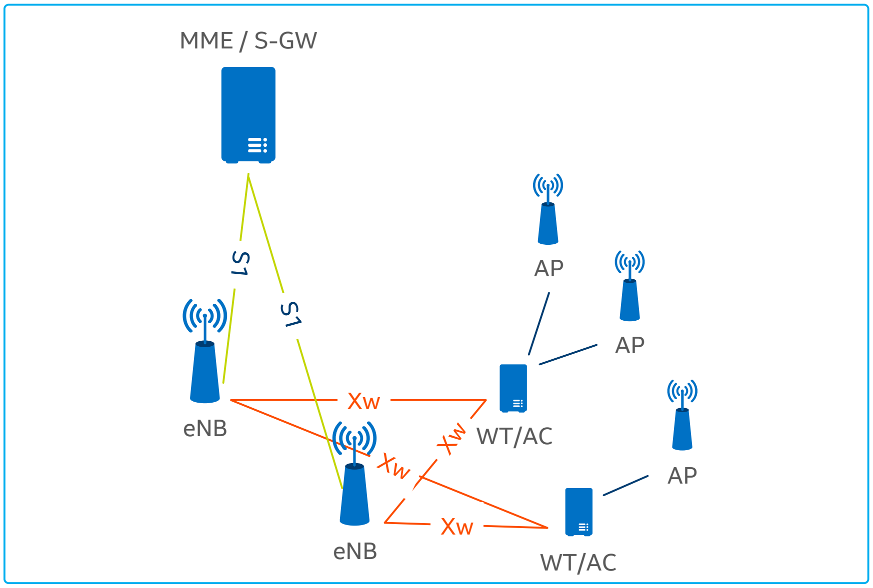
As the WLAN measurement framework is not necessarily linked to LWA, it can also be used for implementing WLAN Self-Optimized Network (SON) features, e.g. Automatic Neighbor Relation (ANR) – to discover which WLAN APs are under eNB coverage. The same measurement framework may also be used in conjunction with alternate radio interworking solutions such as LWIP.

UE mobility between WLAN APs is a tradeoff between fully network controlled mobility, which is commonly used in LTE, and fully UE controlled mobility, which is commonly used in WLAN. Once LWA is activated, the eNB configures the UE with a list of WLAN identifiers (referred to as the WLAN Mobility Set) within which the UE can move without notifying the network. This allows for fast and transparent selection of the WLAN connection providing the best throughput. The most common configuration for deployment is expected to be all APs within the WLAN Mobility Set connected to the same eNB. However, once a UE moves outside of coverage of the Mobility Set, the mobility decision is controlled by the network.

Network Architecture

From the network perspective, there are two options that provide flexibility when looking at deploying LWA - collocated and non-collocated. In the first option, the eNB and the WLAN AP or Access Controller (AC) are integrated into the same device. The collocated option is more appropriate for small cell deployments with integrated WLAN APs. In the second option, the eNB and the WLAN AP/AC are connected via a standardized interface referred to as Xw[6,7,8] through a WLAN Termination (WT) logical node. The non-collocated option is more appropriate for integrating existing WLAN deployments into LWA with minimum changes to existing WLAN infrastructure.

FIGURE 3. NON-COLLOCATED DEPLOYMENT FOR LWA (LTE-WLAN AGGREGATION)



User Equipment Architecture

Unlike LAA, LWA does not require additional radio, antennas or RF components to support data transmission in unlicensed bands, as it utilizes the existing WLAN MAC, PHY and RF. This means that, while LWA is best implemented on mobile devices (UEs) with a dedicated system solution in which LTE and Wi-Fi modems are directly interconnected, it can also be supported on existing hardware (WLAN and LTE modems) with just software changes. In this scenario, the aggregation functionality can be implemented in driver and modem firmware.

As LWA is using the WLAN device for utilizing the unlicensed spectrum (and most often the WLAN device is also supporting Bluetooth radio), its RF resource sharing, spectrum and/or time sharing with non-LWA WLAN and Bluetooth are implemented and optimized within the WLAN device. And, unlike LAA, it does not require complex inter-device coexistence interfaces and protocols.

Security Architecture

LWA supports legacy WLAN authentication methods that have been implemented in most UEs and networks today. These include WLAN EAP/AKA which provides security authentication and protection against replay attacks. The EAP/AKA LWA capability may be beneficial for operators who would like to minimize the impact to existing WLAN infrastructure when deploying LWA, as it allows reusing already deployed AAA infrastructure. Wi-Fi Passpoint is another option. Passpoint allows users to utilize Subscriber Identity Modual (SIM) authentication without entering in any login or billing information. In LWA, Passpoint is not required, but may be used to simplify WLAN deployment.

In addition, following an initial LWA rollout, an operator who is ready to introduce additional LWA features may choose to use optimized WLAN authentication - which is similar to what was defined for DC architecture.

Optimized WLAN authentication is completely contained within the RAN and, therefore, does not require deployment of dedicated AAA servers. Moreover, since core network nodes aren't involved in WLAN authentication, the procedure is faster and enables uninterrupted user experience during handover between LWA WLAN APs. Through this method, the WLAN Pairwise Master Key (PMK) is derived based on LTE credentials and delivered to both the UE and WLAN AP. The PMK is then used in the standard four-way handshake authentication as defined in IEEE 802.11[9].

Deployment Considerations

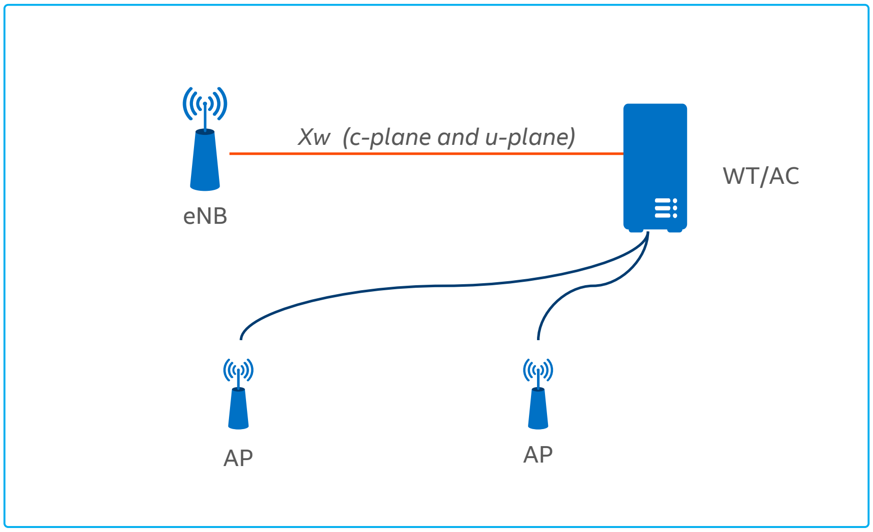
Operators who consider deploying a new technology such as LWA face challenging questions such as how to maximize their investment in existing infrastructure in order to roll out a new technology at minimum cost. While LWA can be used in a similar way to LAA through the deployment of new small cells with integrated LTE and WLAN, it also supports the non-collocated deployment scenario which allows great level of flexibility in supporting different WLAN architectures and backhaul transport networks. In this section, we attempt to address these questions and, in particular, how to support LWA deployment with minimal or no impact on an already deployed WLAN APs using options that have been defined by 3GPP for this purpose.

As described in detail below, LWA features can be deployed in a phased manner with varying degrees of impact on the existing WLAN APs and ACs, including an option where existing WLAN APs do not need to be upgraded in order to support LWA.

Integrated WT/AC

The most natural deployment option for LWA, which is also particularly well suited for enterprise use cases, is when the WT (Wireless Termination) is integrated into the AC (Access Controller), as illustrated in Figure 4.

FIGURE 4. LWA (LTE-WLAN AGGREGATION) DEPLOYMENT WITH THE WT (WLAN TERMINATION) INTEGRATED INTO THE AC (WLAN ACCESSCONTROLLER)

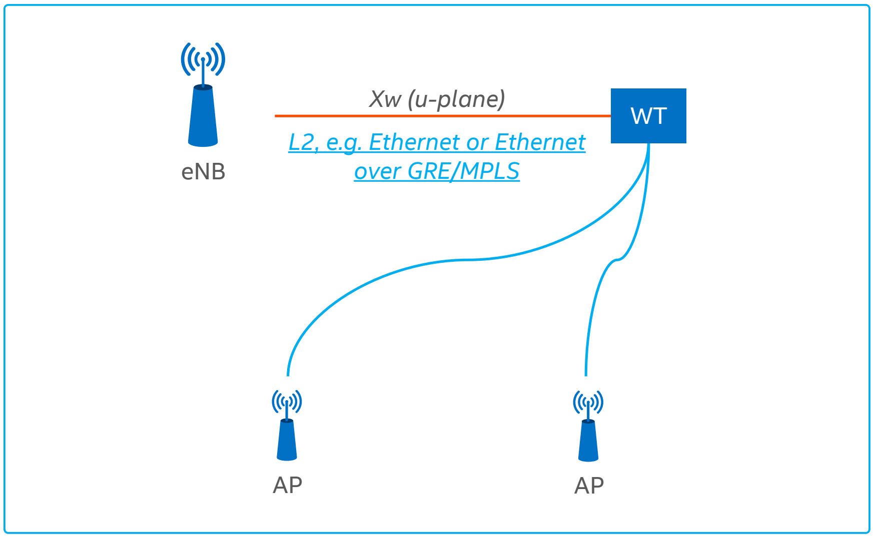


In this scenario, legacy WLAN APs already deployed in the field can be used for LWA and any potential impact to the AC is limited to a software upgrade to support WT functionality (largely limited to the support of the GTP-U and Xw-AP protocols).

Standalone WT

If the WLAN infrastructure is not based on AC, i.e., standalone APs are used, it is possible to deploy LWA without impacting the APs by using a standalone WT, as illustrated in Figure 5.

FIGURE 5. LWA (LTE-WLAN AGGREGATION) DEPLOYMENT USING A STANDALONE WT (WLAN TERMINATION)



In this case, a WT node is deployed on the same Layer 2 network (e.g. Ethernet) as the WLAN APs and ACs. The WT node terminates the Xw user plane protocol (GTP-U), forwarding packets to APs/ACs via Ethernet. Alternatively, any other technology which supports Ethernet bridging, e.g. Generic Routing Encapsulation (GRE) Transparent Ethernet Bridging or Ethernet over Multiprotocol Label Switching (MPLS) can be used between the WT and the AP.

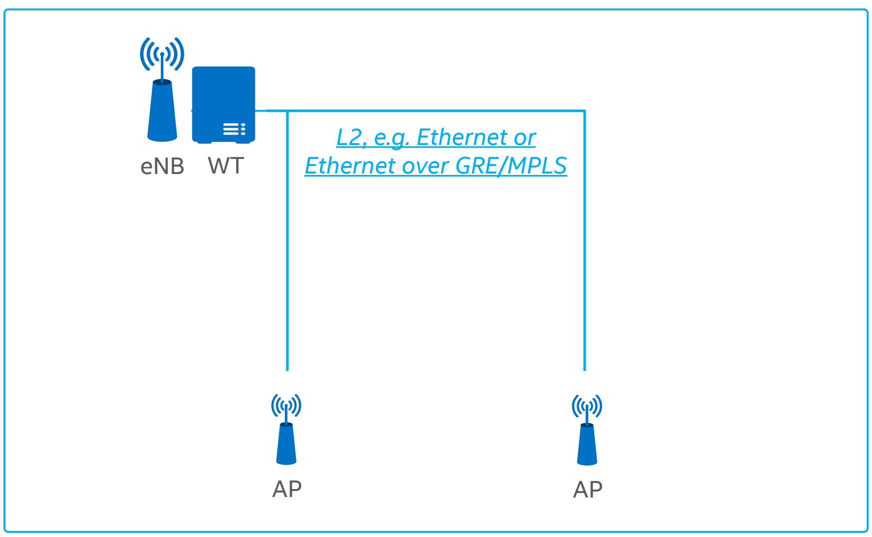
In this scenario, flow control on the Xw interface may not be supported. In order to enable this deployment option without WLAN infrastructure changes, 3GPP has defined a UE-based feedback mechanism (using PDCP) which can be used when network based flow control is not available.

Another limitation of this option is that optimized LWA-WLAN authentication is not supported. However, legacy EAP/AKA authentication may be used.

eNB with integrated WT

Yet another option for deploying LWA with no impact on the existing WLAN infrastructure is to integrate a limited [to user plane only] WT functionality into the eNB, as shown in Figure 6 below.

FIGURE 6. LWA (LTE-WLAN AGGREGATION) DEPLOYMENT USING ENB WITH INTEGRATED WT (WLAN TERMINATION)



This deployment option is similar to the option of standalone WT, with eNB and WT possibly integrated into the same box.

Performance

Because one of the reasons to deploy LWA is performance, it is important to understand LWA performance gains and how these compare to existing LTE/WLAN interworking technologies (e.g. S2b) and new alternative technologies (e.g. LAA and LWIP). For the purpose of LWA evaluation, its performance has been measured based on the related 3GPP evaluation methodology. The results presented are for downlink with 20 MHz WLAN/20 MHz LTE channels, using the IEEE 802.11n WLAN capabilities and non-full buffer FTP traffic model 3. Detailed simulation assumptions are provided in the Annex of this white paper and similar results have been published within the 5G Americas authored report entitled LTE Aggregation and Unlicensed Spectrum[10].

It should be noted that, in practice, LWA gains are expected to be higher than those simulated below, as it will benefit from 802.11ac enhancements. Moreover, as 802.11 technologies evolve, LWA will benefit from further performance enhancements.

LWA and S2b/LWIP

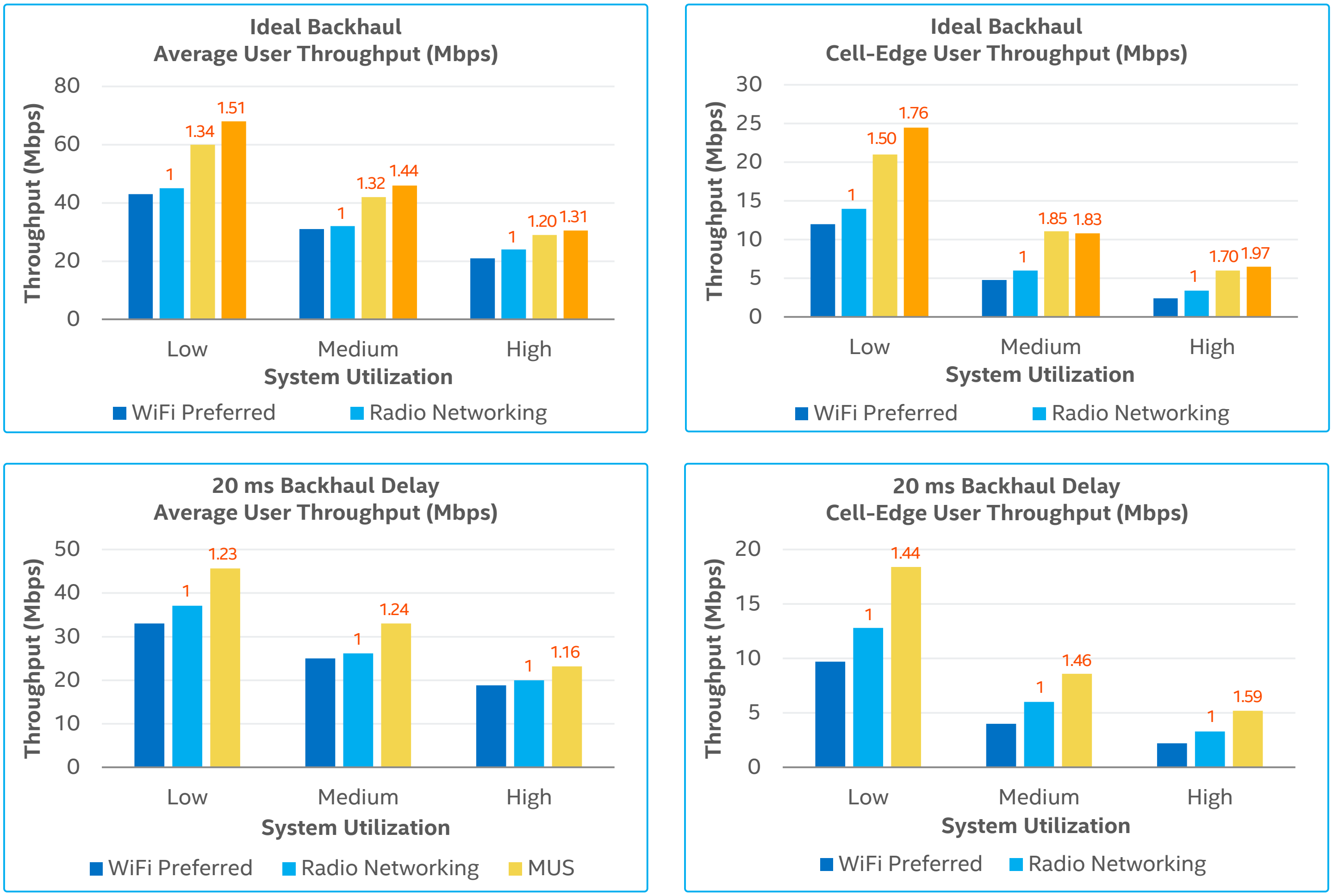
For operators facing the choice of deploying one of the unlicensed spectrum technologies, it is worthwhile to compare the available options in terms of performance gains, cellular and WLAN network impact, and capability to provide useful services.

Figure 7 below illustrates LWA performance gains for non-collocated Het-Net deployments while comparing average and cell-edge performance results across all users with ideal backhaul delay with a non-ideal delay scenario of 20 millisecond. In this illustration, five WLAN APs per macro cell sector are considered with system utilizations of Low, Medium and High corresponding to 20-25%, 40-50% and 60-70% utilization levels, respectively.

The performance of these four different algorithms can be used with LTE/WLAN interworking options to demonstrate:

1. WLAN-preferred which is the conventional method implemented by most current devices.
2. Radio interworking without bearer split, indicative of performance with LWIP and R12/13 radio interworking enhancements, when used together with S2b/NB-IFOM.
3. Multi-user bearer split algorithm (MUS) that may be used with the LWA option for non-collocated deployments[11].
4. Joint queue and joint scheduling algorithm that may be used for the LWA option for the collocated case.

FIGURE 7. PERFORMANCE OF DIFFERENT LTE/WLAN INTERWORKING OPTIONS

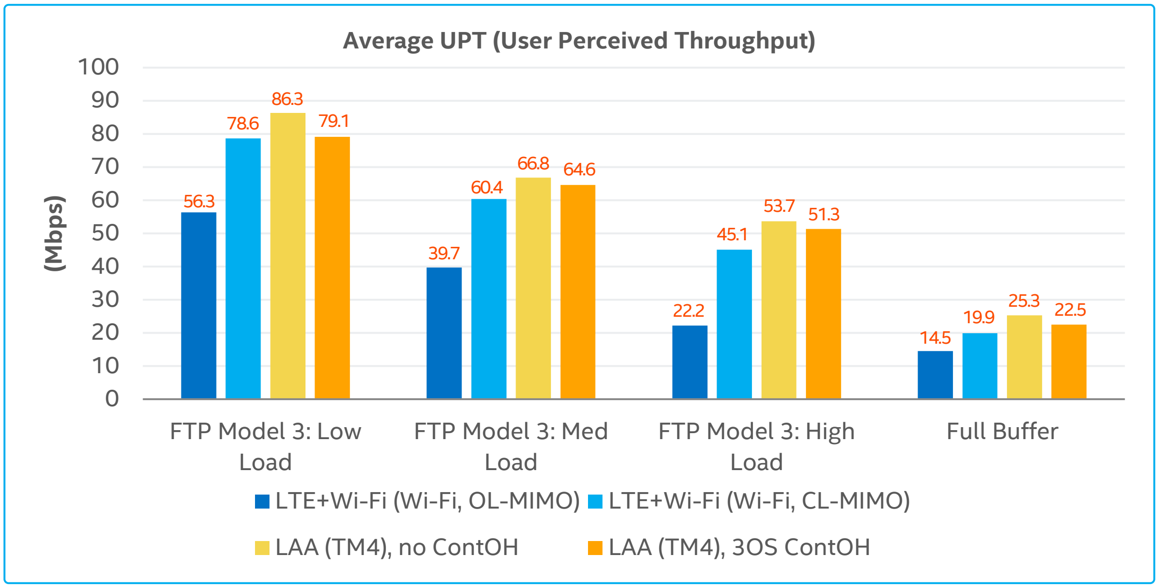


As shown in the upper left graph of Figure 7, LWA with MUS provides 20-30% gains in average user performance compared to radio interworking solutions not supporting bearer split (e.g. S2b and LWIP) even when considering non-collocated deployments. As shown, further gains of 30%-50% may be achieved for the collocated case with the joint queue/scheduling algorithm. The gains are much higher for cell-edge users, as shown in the upper right graph of Figure 7. The LWA gains are preserved with typical backhaul delays (e.g. 20 ms) in non-collocated deployments, as shown in the lower graphs of Figure 7 for both average and cell-edge user throughput, respectively. Further performance improvements beyond that shown for the MUS algorithm are feasible with more advanced bearer splitting algorithms, but will require additional support from the WLAN AP[12].

LWA and LAA

The performance comparison of LWA with LAA is illustrated for the indoor model of use within the 3GPP LAA evaluation methodology with a downlink of 10 MHz for licensed LTE and 20 MHz for WLAN/LTE-U, and FTP model 3 (different file sizes) for a full buffer traffic model. The LTE+Wi-Fi results are reflective of LWA with joint scheduling suited for collocated deployments.

FIGURE 8. PERFORMANCE COMPARISON OF LWA (LTE-WLAN AGGREGATION) WITH LAA (LICENSE ASSISTED ACCESS)



Some initial simulations that showed significant LAA gains were carried out under different simulation assumptions for LAA and LWA, e.g. open-loop MIMO for WLAN and closed-loop MIMO for LAA. However, as shown in Figure 8, under similar assumptions, e.g. if closed-loop MIMO is also used for WLAN and self-carrier scheduling overhead is accounted for LAA, the performance difference between LAA and LWA is negligible.

Looking forward, with enhanced LTE-WRAN aggregation (eLWA) adding 60 GHz support in 3GPP Release-14, LWA, with 2 GHz bandwidth, is expected to outperform LAA, beyond what is shown in Figure 7.

LWA Comparison with LAA, S2b and LWIP

Performance is not the only factor that operators face when it comes to deployment of unlicensed spectrum technologies. Table 1 below provides a comparison of LWA, LAA, LWIP and S2b in terms of identified key performance indicators.

TABLE 1. COMPARISON OF LWA, LAA, LWIP AND S2B ACROSS DIFFERENT KPIS

	LWA	LAA	LWIP	S2B
Performance gains[a]	high	high	medium	medium[b]
Single network for licensed and unlicensed[c]	yes	yes	partial[d]	no
Optimized for Collocated eNB/AP deployment	yes[e]	yes	no[f]	no[f]
Support Non-collocated eNB/AP deployment	yes	no	yes	yes
LTE infrastructure impact	medium	new hardware	high[g]	high[h]
WLAN infrastructure impact	low[i]	n/a	none	none
Same infrastructure re-use for non-cellular WLAN-only users[j]	yes	no	yes	yes
Support for uplink	no[k]	no[k]	yes	yes

Notes:

[a] Performance gains have been evaluated compared to conventional WLAN offload technologies without radio interworking enhancements. LWA provides 20-50% gains in average user performance under medium load conditions compared to LWIP/S2b, mainly due to split bearer support. LAA gains over LWA are negligible.

[b] LWIP is expected to have some advantages over S2b due to shorter delay, as LWIP is anchored in RAN rather than CN.

[c] Integration at the radio access network level with LWA, LAA and to a lesser extent LWIP makes unlicensed spectrum transparent for the core network, eliminating the need to manage two separate networks for licensed and unlicensed.

[d] LWIP does not require ePDG, however dedicated AAA server is still needed.

[e] LWA allows for additional performance gains in the collocated deployment.

[f] Depending on LWA deployment options chosen by operators, LWA can be deployed with software upgrade to AC only, without any impact on the deployed legacy APs.

[g] All eNBs need to be upgraded to support the security gateway LWIP-SeGW.

[h] Dedicated core network node (ePDG) needs to be deployed.

[i] LWIP and S2b can be deployed in the collocated scenario, however in this case the overhead of using IPsec is hard to justify. LWA and LAA can exploit the benefits of the collocated deployment.

[j] WLAN only users are, e.g. PC/tablet users without cellular connectivity.

[k] Uplink aggregation support is being added to LWA and LAA in Release-14, Release-13 supports uplink on LTE only.

Comparison

Following the summary in Table 1, operators who are planning to roll out a large number of new small cells and have no interest in servicing WLAN-only users, may prefer to use an LAA solution. This option requires investment in new hardware to deploy a large number of small cells but may be a compelling choice for operators who are familiar with 3GPP technologies and are not interested in serving users who have WLAN connectivity only (e.g. laptops and tablets).

Operators that cannot afford to make changes to their existing WLAN infrastructure may accept the performance gap and impact on cellular infrastructure and choose to deploy LWIP or stay with S2b. It has the benefit of having no impact to the WLAN infrastructure but the difference in performance between LWIP and LWA/LAA is substantial and the impact on cellular infrastructure and its ability to support large number of IPsec tunnels in eNBs is not small and may require hardware upgrades. Moreover, operators who have already rolled out S2b may need to justify additional investment in LWIP - given the marginal improvement of LWIP compared to S2b.

Operators that want to serve both cellular and WLAN users with maximum performance may want to consider an LWA implementation. LWA has performance gains that are similar to LAA and will have a moderate impact on cellular infrastructure as LWA architecture is based on DC. It also allows for serving both cellular and WLAN-only users (e.g. laptops and tablets). LWA can be rolled out in a phased manner without any changes to legacy APs in the initial phase and in support of both standalone WLAN APs, integrated new small cells that have both cellular and WLAN connectivity, or a mix of the two.

Release-14 LWA

The evolution of LWA continues in 3GPP Release 14 with the recently approved Enhanced LWA (eLWA) work item. Release 14 eLWA capability adds uplink aggregation support, mobility enhancements and support for 60 GHz (WiGig).

The uplink aggregation will be beneficial for multiple scenarios, including social use case, such as gaming and sharing of multimedia content. Mobility enhancements will reduce potential LWA service interruption during LTE handover. And aggregation with WiGig in 60 GHz will unlock the potential of 2GHz bandwidths for LWA. All of this provides further performance gains compared to LAA.

5G

Unlicensed spectrum, and WLAN interworking in particular, will continue to be important to operators in the coming 5G era. The 3GPP NR (New RAT) study item already includes requirements for tight interworking with WLAN and licensed assisted operation. And, although it may be too early to predict which WLAN interworking scenarios will be standardized and deployed with 5G, LWA and eLWA can provide a solid framework upon which 5G interworking with WLAN can be built. Additionally, the IEEE community is currently evaluating their role in 5G with LWA/eLWA being one of the preferred options - allowing for IEEE to play a role in 5G development[13].

Summary and Conclusion

In this paper, LWA architecture and operation, performance and deployment considerations have been examined and LWA, when shown under similar assumptions, provides comparable gains to those reported for LAA. Moreover, with the addition of 60 GHz to eLWA in 3GPP Release-14, LWA with 2GHz bandwidth is expected to outperform LAA. In fact, LWA provides substantial performance gains over LTE/WLAN integration technologies which do not support split bearer, such as LWIP and S2b.

This paper also looks at LWA deployment options to demonstrate how non-collocated LWA can be deployed with minimum impact to the existing WLAN infrastructure which is limited to a software upgrade of the AC only and without any changes required for the deployed legacy WLAN APs. In conclusion, deployment recommendations are provided, based on potential operator service requirements and deployment constraints.

Unlicensed technologies are going to play an important role in responding to the growing demands from mobile operators and the Wi-Fi community. LWA provides technical and market advantages for consideration. Tighter convergence through the building out of a network of access points and integrated small cell infrastructure is an approach that may prove to be attractive for operators that have well established Wi-Fi services and are aiming to operate in both the cellular and Wi-Fi markets.

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Annex A - LWA vs. S2b/LWIP Simulation Assumptions

System level performance to characterize Layer 2 throughput enhancement:

- Based on 3GPP methodology (36.814, 36.819, TR 36.842).
- Downlink only.
- 20 MHz WLAN/20 MHz LTE channels.
- WLAN simulations models 802.11n contention based MAC.
- Non full buffer FTP traffic model 3 (vary packet size, arrival rate or users to change system load)
- Cell association thresholds controlled by macro cell

Outdoor HetNet deployments w/ 3 sector macro cells:

- Non-collocated case: macro-cell + Wi-Fi only small cells.
  - Ideal and non-ideal backhaul (up to 20 millisecond latency)

Annex B - LWA vs. LAA Simulation Assumptions

Based on 3GPP LAA evaluation methodology in 3GPP TR 36.889.

Main assumptions:

- Indoor model in 36.889 Annex 1 (ITU InH channel model, w/ 4eNBs and 10 UEs inside a building)
- 10 MHz (licensed LTE) with 20 MHz (WLAN/LTE-U)
- UE assumed to be in coverage (UEs w/ RSRP > -82 dBm are simulated)
- FTP model 3 (different file sizes) /Full buffer traffic model
- Downlink only
- Antenna: DL 2x2; UL 1x2

WLAN assumptions:

- Open loop SU-MIMO w/o feedback. Link adaptation (sample rate algorithm*)
- Closed loop SU-MIMO w/ ideal feedback (SVD based pre-coding)

LAA assumptions:

- Dynamic small cell on/off based on "Listen before Talk" (LBT)
- LBT implementation similar to WLAN (see Backup)
- Control Overhead:
- No overhead (Assumes cross carrier scheduling on licensed carrier)
- 3 OFDM symbols for self-carrier scheduling

About the Author

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Sasha Sirotkin is a senior wireless architect in the Next Generation and Standards group at Intel Corporation. In this role, his primary focus areas are unlicensed spectrum and radio access network architecture. Mr. Sirotkin has represented the company in 3GPP TSG WGs RAN2 and RAN3, as well as 3GPP TSG RAN. In 3GPP, he has served as the rapporteur for the WLAN/LTE Radio Interworking work and study items in Release-12 as well as LTE-WLAN Aggregation (LWA) work item in Release-13. Currently, he is the rapporteur for the Enhanced LWA (eLWA) work item in 3GPP Release-14.

Mr. Sirotkin joined Intel in 2010 and has over 15 years of experience in wireless communications. Previously, he worked at the start-up Comsys and Texas Instruments.

Mr. Sirotkin holds B.Sc. degrees in Computer Science and Physics and a M.Sc. degree in Applied Statistics and Astrophysics from Tel-Aviv University in Israel.

List of Acronyms

3GPP	3rd Generation Partnership Project
AAA	Authentication, Authorization, and Accounting
AC	Access controller
AKA	Authentication and Key Agreement
ANDSF	Access Network Discovery and Selection Function
ANR	Automatic neighbor relation
AP	Access Point
CN	Core Network
DC	Dual connectivity
DL	Downlink
EAP	Extensible Authentication Protocol
eLWA	Enhanced LTE wireless LAN aggregation
eNB	evolved Node B base station
ePDG	Evolved Packet Data Gateway
GRE	Generic Routing Encapsulation
LTE	Long Term Evolution
LTE Bearer	In an LTE network, a bearer is a packet flow between the access equipment and the PGW with defined QoS (quality of service) characteristics
LTE-LAA	Licensed Assisted Access LTE
LWA	LTE WLAN aggregation
LWAAP	LWA Adaptation Protocol
LWIP	LTE/WLAN radio level integration with IPsec tunnel
MAC	Media Access Control
MME	Mobility Management Entity
MPLS	Multiprotocol Label Switching
NSWO	Non-Seamless WLAN Offload
P-GW	Packet Data Network Gateway
PDCP	Packet date convergence protocol
PDU	Protocol Data Unit
PHY	Physical Layer
PMK	Pairwise Master Key
RAN	Radio access network
RAT	Radio access technology
RLC	Radio Link Control
RF	Radio frequency

S2b	an IPsec based interface between an ePDG and an untrusted WLAN access
S-GW	Serving Gateway
SIM	Subscriber identity module
UE	User Equipment
UL	Uplink
Wi-Fi	WLAN based on IEEE 802.11 standard
WLAN	Wireless Local Area Network
WT	Wireless termination

Definitions

Licensed LTE: Current LTE technology deployed by operators and used by smartphones and other devices, which works in licensed spectrum. With the increase in data demand on licensed spectrum there is an ongoing study and discussion regarding using LTE in unlicensed spectrum (which is traditionally used by other technologies like Wi-Fi and BT).

Licensed Assisted Access (LAA): LAA is a technology to enable LTE in unlicensed spectrum. LAA uses the Carrier Aggregation (CA) feature of LTE to aggregate two streams (anchor in licensed LTE spectrum and secondary cell in unlicensed LTE spectrum). The initial version of LAA is standardized in 3GPP Release 13.

LTE Wi-Fi Aggregation (LWA): LWA uses a dual-connectivity (anchor/booster) based framework to integrate Wi-Fi as an integral part of a 3GPP radio access network. It enables simultaneous transmission of packets belonging to the same stream over LTE and Wi-Fi (bearer-split). LWA introduces a standards based interface between LTE eNB and the WLAN network to optimize traffic aggregation across LTE and Wi-Fi links. LWA has been standardized in 3GPP Release 13 and is being enhanced in Release 14 as part of Enhanced LWA (eLWA) work item, adding uplink and 60 GHz support.

LTE Wi-Fi Radio Level Integration with IPSec Tunnel (LWIP): LWIP, like LWA, integrates Wi-Fi in the 3GPP LTE RAN, but uses an IP-sec tunnel between the eNB and the terminal device to transparently route a traffic stream over the WLAN network.

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