3GPP LTE-WLAN Aggregation

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Agenda

• Background
• LTE-WLAN Interworking (LWI)
• LTE-WLAN Aggregation (LWA)
• Enhanced LWA (eLWA)
• LTE/WLAN Radio Level Integration with IPsec Tunnel (LWIP)
Background

• Growing traffic demand

• Cellular vs. Wi-Fi
  – Competition -> Interworking -> Aggregation

• Licensed + Unlicensed for operators
  – R12: RAN-Assisted LWI
  – R13: LWA & RAN- Controlled LWI
  – R13: LWIP
  – R14: Enhanced LWA
RAN-assisted LTE WLAN interworking in Rel-12

- WLAN offload RAN evaluation
  - Provide measurement results required as defined in ANDSF to upper layers
  - Evaluate: LTE is bad and WLAN is good for a time interval

- Dedicated WLAN offload configuration
  - wlan-OffloadInfo-r12 (in RRC message)
    - **Thresholds**
      - E-UTRAN signal strength, WLAN channel utilization, WLAN backhaul data rate, WLAN signal strength and Offload Preference Indicator
    - T350-r12 (5min~180min)

- Broadcast offload configuration (in SIB17)
  - WLAN-Identifiers-r12: SSID, BSSID, HESSID
  - WLAN-OffloadConfig-Thresholds
LWA Overview

- Aggregates LTE and WLAN at **RAN level**
  - WLAN AP only interacts with the LTE eNB;
  - **No interaction with LTE Core Network**
- Key drivers: performance, mobility, eliminating need for WLAN-specific Core Network nodes
- LWA is controlled by eNB, based on UE measurement reporting
- Formally completed in March 2016 (Rel-13)
• Deployment choice to integrate the WT into APs or deploy as a standalone network node
• How information is exchanged between WT and APs is out of 3GPP scope
LWA

Data Plane

- Allow a single bearer to utilize LTE and WLAN simultaneously
  - **Split** and **switched** bearers are supported
- In R13, LWA supports aggregation in **DL only**, while UL transmission is always on LTE (RLC AM)
- Packets (PDCP PDUs) belonging to LWA bearer can be sent by eNB via LTE or WLAN simultaneously
- PDCP PDUs sent via WLAN are encapsulated in LWA Adaptation Protocol (LWAAP) which carries **DRB ID**
  - Multiple-bearer offloading is possible
- LWA uses **EtherType 0x9E65**

Split -> reordering
LWA

LWA activation and deactivation are **controlled by eNB**

- eNB configures **WLAN mobility set** for UE
- WLAN mobility set is a group of WLAN APs identified by SSID(s), HESSID(s) or BSSID(s)
- Mobility within WLAN mobility set is controlled by UE
- Mobility outside of WLAN mobility set is controlled by eNB
- Release LWA configuration when got configured, upon handover or entering RRC_IDLE
WLAN Measurements

• Measurement report contains: WLAN IDs, RSSI, STA count, backhaul rate, admission capacity, channel utilization and other metrics

• Reports are events triggered by RSSI thresholds:
  • Event W1: LWA activation;
  • Event W2: Inter WLAN mobility set mobility;
  • Event W3: LWA deactivation.

• WLAN measurement framework is common to LWA, RCLWI, and LWIP
WLAN Security

• EAP/AKA 802.1x authentication may take time, so 3GPP decided to define an optimized WLAN authentication procedure

• When **optimized WLAN authentication** is used:
  • eNB derives a key based on $K_{eNB}$ and WT Counter
  • eNB sends the key to WT, WT makes it available to APs in WLAN mobility set
  • UE derives the same key autonomously (based on WT Counter received from eNB and $K_{eNB}$)
  • Used as the Pairwise Master Key (PMK) in **4-way handshake** as defined in IEEE 802.11
**LWA: Xw**

**Control Plane**

- eNB uses WT Addition/Modification Request to request/modify preparation of resources for LWA in WT
  - UE id, WLAN security key, bearer info (including QoS), WLAN mobility set and other
- WT Status Report is used by WT to report WLAN measurements per BSS
  - BSSID, BSS load, WAN metrics and available channel utilization

WT Association Confirmation is used by WT to indicate that a UE successfully connected to WLAN
LWA: Xw

Data Plane

- Xw data plane uses GTP-U on top of UDP for data transfer from eNB to WT
- DL for data forwarding
- UL for feedback/flow control
- Optional *Downlink data delivery status* procedure is used by WT to indicate its buffer status and lost PDUs to eNB
  - Every PDU is assigned a Xw-U sequence number
**LWA:**

**UE Feedback**

- **WLAN Status Monitoring**
  - successfulAssociation, failureWlanRadioLink, failureWlanUnavailable, failureTimeout

- eNB may trigger status reporting from UE on air interface (at PDCP layer) using either:
  - **PDCP status report**: First Missing PDCP SN, bitmap of received PDCP SDUs
  - **LWA status report**: First Missing SN (FMS), Number of Missing PDUs (NMP) and Highest Received SN on WLAN (HRW)

- **NOTE**: eNB can derive information about packets lost on LTE from RLC layer, since only RLC Acknowledged Mode (AM) is allowed for LWA

<table>
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<tr>
<th>D/C</th>
<th>PDU Type</th>
<th>FMS</th>
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<td>FMS (cont.)</td>
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<td>Bitmapₙ (optional)</td>
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<td></td>
<td></td>
<td>Bitmapₙ (optional)</td>
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Oct 1

Oct 2

Oct 3

Oct 2+N
Establish a UE context at the WT in order to provide WLAN resources to the UE.
LTE-WLAN Radio Level Integration and Interworking Enhancement in Rel-14

Mar. 16 - Mar. 17, WID: RP-160923

• Objective of SI/WI
  – Uplink transmission on WLAN, including UL bearer switch and split
  – Mobility optimizations, e.g. intra and inter eNB handover without WT change
  – Potential enhancements to support 60 GHz new band and channels (e.g. in measurements) and increased data rates for 802.11ax, 802.11ad, and 802.11ay (e.g. by PDCP optimizations)
  – Additional information collection and feedback e.g. for better estimation of available WLAN capacity (by additional signaling on both Uu and Xw) to improve LWA performance
  – Automatic Neighbor Relation (ANR) for LWA e.g. for discovery of WLANs under eNB coverage
Uplink

eLWA

- **Data Split Threshold, BSR**
  - For LWA bearers, only the data that may be sent over LTE (i.e., excluding UL data already sent or decided to be sent over WLAN) is considered as “data available for transmission”.

- **UL routing/MAC address**
  - WT MAC Address via RRC message
  - Does not preclude other solutions being used in deployments.
  - LS to RAN3 about sending MAC address via Xw to WT

- **PDCP data recovery**
  - PDCP retransmission of packets sent over WLAN is not supported during PDCP re-establishment of LWA bearer, and change of LWA bearer to LTE bearer, even if PDCP status report indicates that the PDCP PDU is missing.

- **RLC UM for LWA bearer**
  - May be concluded/introduced later but not in eLWA WI
Intra and inter eNB handover without WT change

LWA is activated for the UE

1. Handover Request
2. WT Addition Request
3. WT Addition Request Ack.
4. Handover Request Ack.
5. RRC Connection Reconfig.
6. WT Release Request
7. Random Access Procedure
8. RRC Connection Reconfiguration Complete
9. SN Status Transfer
10. Path Switch Request
11. Path Switch Request Ack.
12. UE Context Release

LWA is activated for the UE
eLWA

- LWA end-marker packet (PDCP Control PDU).
- In DL, the source eNB sends the last PDCP packet to be send on WLAN followed by LWA end-marker with last SN to the WT and then stops sending more packets to the WT.
- For the DL, UE continues using the source eNB PDCP key for PDCP packets until it receives the “LWA end-marker with last SN”, then the UE starts using target eNB PDCP key for PDCP packets after the indicated SN.
- For the UL, the UE starts using target eNB PDCP key and sends the LWA end-marker to the WT immediately after the HO command is received.
- The applicability of HO optimization without WT change will be signaled to the UE via RRC message to indicate both directions.
Feedback

eLWA

— eNB can configure UE to measure on 60Ghz band if UE supports

— Suspend/resume mechanism
  • WLAN suspension should trigger UE PDCP status report if configured by the eNB during the resumption

— Periodic WLAN measurements
  • Periodic WLAN measurement reporting will be supported in Rel-14, based on UE capability.
  • Support reportStrongestCells for periodic WLAN measurements. Serving WLAN AP is always reported first in the list.
  • Utilize the existing ReportInterval IE also for periodic WLAN measurements.

— Throughput estimate
  • Not agreeable in Rel-14
  • LS to IEEE on accuracy requirement
ANR

- Reporting of unknown WLANs
  - TBD in [97#03][LTE/eLWA] Unknown WLAN 306 CR (Nokia)

UE capabilities

- WLAN data rate capability to be signaled as part of LWA capability
  - UE reports a supported WLAN data rate in UE capabilities
  - Granularity of the reporting can be discussed offline
LWIP

Overview

- UE uses WLAN via IPsec tunnel between eNB and UE
- **Key drivers: fast time to market, use of legacy WLAN infrastructure**
- WLAN is hidden from CN
  - Except for WLAN authentication – EAP/AKA
- Controlled by eNB, based on UE measurement reporting
- IPsec tunnel is terminated in LWIP-SeGW and is transparent to WLAN infrastructure
- No standardized network interfaces in LWIP
- Single IPSec tunnel per UE for UL and DL data
- Formally completed in March 2016 (Rel-13)
LWIP
Data Plane

- UL and DL supported over WLAN
- In UL, IP packets are encapsulated in LWIPEP to carry bearer ID for routing purposes
- Bearer differentiation is not needed in DL (no LWIPEP)
  - packets received from IPsec are forwarded directly to upper layers

**No re-ordering** support:
- not expected to send packets on a data radio bearer via LTE and WLAN simultaneously in Rel13
**LWIP Control Plane**

- **Activation and deactivation is controlled by eNB**
  - LWIP is torn down when handover/re-establishment/RRC idle

- **When LWIP is activated**
  - eNB sends WLAN mobility set, bearer info and LWIP-SeGW IP address
  - After WLAN association and EAP/AKA authentication, UE establishes IPSec connection with LWIP-SeGW using Internet Key Exchange (IKE)
  - IPsec keys are derived (by eNB and UE) based on $K_{eNB}$
  - Re-uses same WLAN measurement reporting framework as LWA
  - Re-uses same WLAN mobility concept as LWA
**LWIP Aggregation in TEI14**

- **Aggregation** for LWIP in **both UL and DL**.
  - Rel-14 LWIP to use LWIPEP encapsulation in DL for PDUs sent over WLAN.
  - Rel-14 LWIP to use LWIPEP encapsulation in UL and DL for PDUs sent over LTE.
- LWIP aggregation is allowed using the LWIPEP header **sequence number**.
  - Re-ordering is supported in R14 (up to implementation)

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Proposed by Nokia, supported by AT&T, Sprint, Apple, Broadcom in RAN2#96
Future plan with non-3GPP tech in 3GPP

3GPP RAN has approved a requirement for TR38.913 on interworking with non-3GPP. Requirement says:

- **10.5.1 General**
  - 3GPP system shall support procedures for interworking with non 3GPP RATs.

- **10.5.2 Interworking with WLAN**
  - The next generation access network shall support interworking with WLAN. The number of solutions selected should be minimized.

Exploring further involvement of IEEE in this work should be initiated by liaison to 3GPP.
### Brief Comparison

<table>
<thead>
<tr>
<th></th>
<th>eNB control</th>
<th>WLAN measurements reporting</th>
<th>Offload granularity</th>
<th>WLAN traffic direction</th>
<th>Feedback/flow control</th>
<th>Fast WLAN authentication</th>
<th>WLAN infrastructure impact</th>
<th>New network nodes</th>
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<tbody>
<tr>
<td>eLWA</td>
<td>Yes</td>
<td>Yes</td>
<td>Split bearer</td>
<td>DL + UL</td>
<td>Yes</td>
<td>Yes^2</td>
<td>Yes^4</td>
<td>WT</td>
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<td>LWA</td>
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<td>Yes</td>
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<td>Yes</td>
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<td>DL + UL</td>
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<td>No^3</td>
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<tr>
<td>RALWI</td>
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<td>No</td>
<td>APN granularity</td>
<td>DL + UL</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

1. When a bearer is configured to use IPsec, LTE DRB configuration remains
2. LWA UE only performs 4-way handshake (if network uses the eNB based authentication)
3. LWIP UE performs WLAN native 802.1x EAP/AKA authentication, IP address acquisition and IPsec tunnel establishment
4. Impact due to eNB based authentication mechanism, if used by network. Also EtherType.
thank you
LWA
• Stage-2 high level description – TS 36.300, section 22A.1
• Stage-3 data plane (PDCP) – various sections in TS 36.323
• Stage-3 data plane (LWAAP) – TS 36.360
• Stage-3 control plane (RRC) – various sections in TS 36.331
• Stage-3 control plane network interface (Xw) – TS 36.463, TS 36.462, TS 36.461
• Stage-3 data plane network interface (Xw) – TS 36.465, TS 36.464
• Stage-3 security aspects – TS 33.401, section X (section number to be allocated)

LWIP
• Stage-2 high level description – TS 36.300, section 22A.3
• Stage-3 control plane (RRC) – various sections in TS 36.331
• Stage-3 data plane – TS 36.361
• Stage-3 security aspects – TS 33.401, section Y (section number to be allocated)
• Specifications are available for download here: http://www.3gpp.org/ftp/Specs/latest/Rel-13/

eLWA
• Rel-14 eLWA Work Item Description (WID) - RP-160600

FeLWA
• Rel-15 FeLWA Motivation – RP-162198
Dual Connectivity

- Increase UE throughput especially for cell edge UEs
- Mobility robustness enhancement
- Reducing signaling overhead towards the CN due to frequent handover

Source: TS 36.842

Macro cell

Carrier 1 (F1)

Non-ideal backhaul (e.g. X2)

Small cell

Carrier 2 (F2)

U-plane data

U-plane data

• Increase UE throughput especially for cell edge UEs
• Mobility robustness enhancement
• Reducing signaling overhead towards the CN due to frequent handover

Source: TS 36.842