2020-10-13 Tutorial Agenda & opening slides

Date: 2020-10-06

Authors:

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Abstract

This document contains the agenda and intro/closing slides for the 2020-10-13 802 Tutorial on WLAN & 3GPP interworking

10am Eastern Oct 13th, 1 hour 20 minutes

Teleconference meeting information: http://ieee802.org/802tele_calendar.html

Teleconference reminder:

Please use the chat window to request to be in the queue.
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Tutorial Agenda

5 mins Welcome and introduction – Dorothy STANLEY

Welcome, P&P reminders, attendance reminder, brief remarks on the topic

50 mins -Topic presentations

35-40 minutes – 802.11 WLAN and 3GPP 5G System Interworking – Binita GUPTA

10-12 mins – QoS Considerations - Hyun Seo OH

7-10 mins Work underway & Completed in AANI – Joseph LEVY

10 mins Q&A

Closing Remarks – Dorothy STANLEY

Attendance reminder, straw poll on electronic meeting for tutorial

Policy reminders

Guidelines for IEEE-SA Meetings

- All IEEE-SA standards meetings shall be conducted in compliance with all applicable laws, including antitrust and competition laws.
  - Don’t discuss the interpretation, validity, or essentiality of patents/patent claims.
  - Don’t discuss specific license rates, terms, or conditions.
    - Relative costs of different technical approaches that include relative costs of patent licensing terms may be discussed in standards development meetings.
      - Technical considerations remain the primary focus
  - Don’t discuss or engage in the fixing of product prices, allocation of customers, or division of sales markets.
  - Don’t discuss the status or substance of ongoing or threatened litigation.
  - Don’t be silent if inappropriate topics are discussed … do formally object.

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IEEE

02 January 2018

Policy Slide:

https://development.standards.ieee.org/myproject/Public/mytools/mob/preparslides.pdf

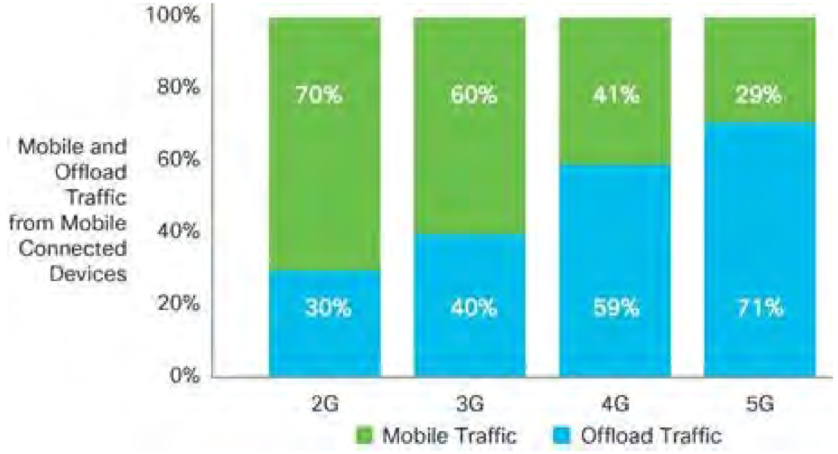
Attendance:

https://imat.ieee.org/wg524200043/attendance-log?d=10/13/2020&p=3168600005&t=524200043

IEEE 802.11 components are now and will be an important part of carrier deployments continuing into the future

Today's 3/4G networks include 802.11 technologies

- For offload: More traffic is offloaded from cellular networks (on to Wi-Fi) than remains on cellular networks (Cisco VNI 2019)
- Use of 802.11/Wi-Fi on mobile devices is significant and increasing
- For Wi-Fi calling and internet access



Wi-Fi carries most public & private Internet traffic worldwide

- Between 50-80% depending on the country

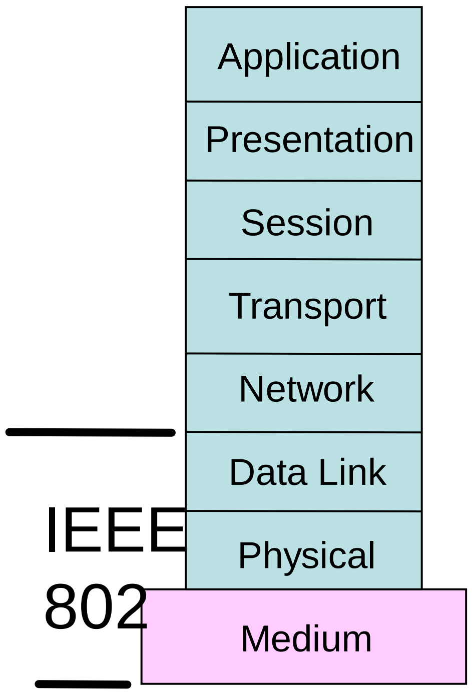
5G Interworking natively incorporates 802.11 systems

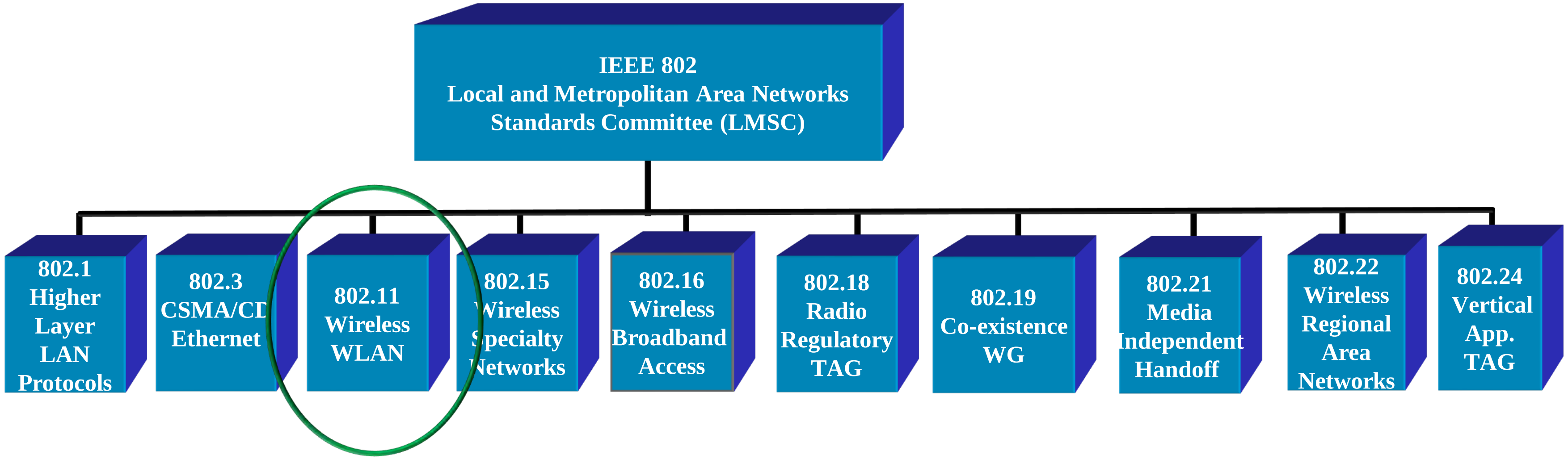
- 802.11/Wi-Fi is a Peer Radio Access Technology with LTE and NR in the 5G Architecture
- 5G capable cellular mobile devices will continue to rely on 802.11 components for internet access and services

IEEE 802 LAN/MAN Standards Committee

- Focus on **link and physical layers** of the network stack
- Leverage IETF protocols for upper layers

OSI Reference Model

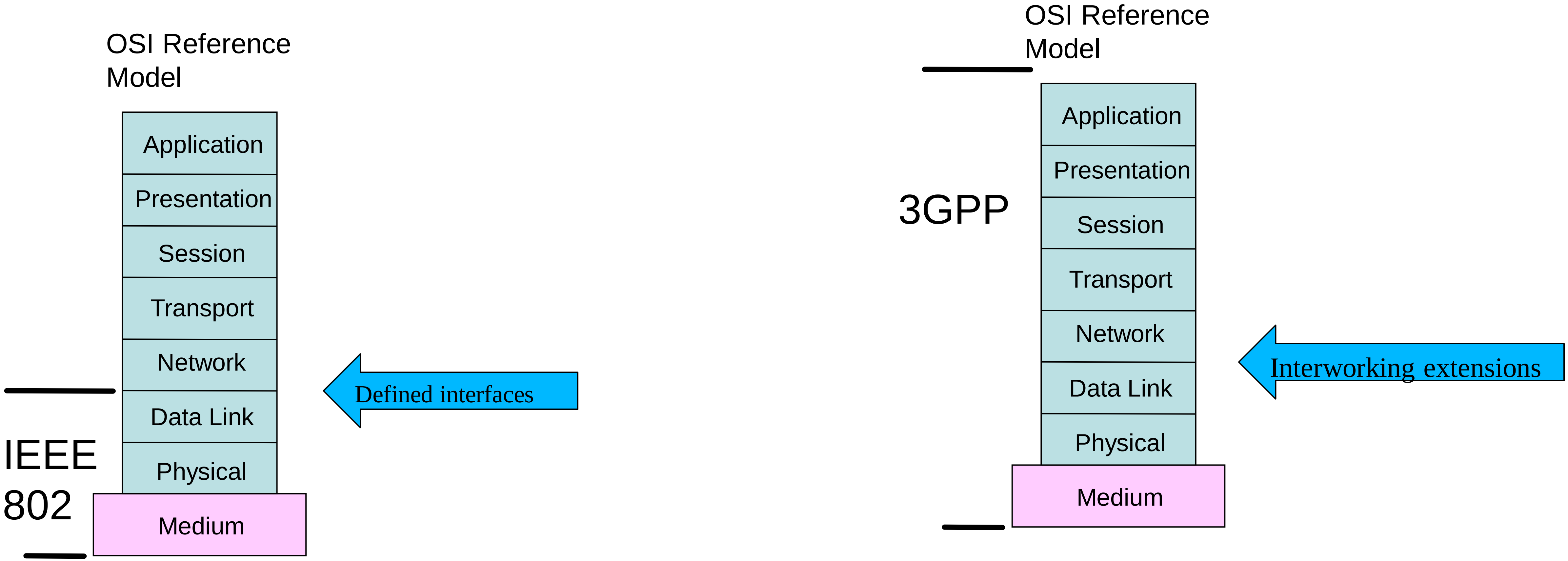




IEEE 802.11 WG Voting Members: 300+

802.11 Focus is on the interface in 3GPP systems

- Focus on **link and physical layers** of the network stack
- Leverage IETF protocols for upper layers



Q&A

Please use the chat window to request to be in the queue.

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Straw poll on meeting format

The electronic format for the tutorial is

(a) Beneficial, continue

(b) I prefer the in-person format

(c) Abstain

Thank you for attending

References

This document: https://mentor.ieee.org/802.11/dcn/20/11-20-1573

Binita GUPTA: https://mentor.ieee.org/802.11/dcn/20/11-20-1579

Hyun Seo OH: https://mentor.ieee.org/802.11/dcn/20/11-20-1562

Joseph LEVY: https://mentor.ieee.org/802.11/dcn/20/11-20-1574

802.11 WLAN and 3GPP 5G System Interworking

Tutorial at IEEE 802 Plenary, October 2020

Date: 2020-10-06

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Abstract

This document contains the tutorial slides for the 802 Tutorial on "802.11 WLAN and 3GPP 5G System Interworking"

It covers the overall system perspective on the integration and interworking of 802.11 WLAN access networks with the 3GPP 5G system. It provides a system overview of the 5G and WLAN interworking architecture, related functions, procedures, policies and interfaces as defined by 3GPP Releases 15 and 16. It highlights some key technical issues and gaps related to enabling WLAN and 5G system interworking and provides recommendations to guide and facilitate standardization effort to address these issues within the Wi-Fi related standards and/or 3GPP standard.

A technical report is submitted in IEEE AANI SC on WLAN and 5G interworking "**Technical report on the interworking between 3GPP 5G system and WLAN**" (**IEEE 802.11-20/1376r0)**

Outline

- **Background: WLAN and 5G Interworking**
- **WLAN Integration Architecture**
    - Untrusted and Trusted WLAN integration
    - Support for Wi-Fi only devices
- **Interworking Related Functions**
- **Interworking Challenges and Gaps**
- **Technical Recommendations**
- **Future Work – TSN Support**

Background: WLAN and 5G Interworking

- With continued advancements in Wi-Fi (Wi-Fi 6/6E, Wi-Fi 7), Wi-Fi is well positioned to carry new breed of 5G applications e.g. AR/VR, industrial IoT, edge computing, autonomous driving
- New 5G use cases have varied set of requirements on throughput, latency, coverage and reliability and can benefit from combined resources from 5G and Wi-Fi access networks
- Interworking between Wi-Fi and 5G can address new market opportunities for emerging verticals and enterprises e.g. Industrial IoT and Connected Cities
- Wi-Fi and 5G interworking enables seamless and interoperable services across 3GPP and Wi-Fi access

Interworking can be achieved at three different levels:

Cloud/App Level Interworking
- ❑ Through above IP protocol e.g. MPTCP or MPQUIC. Deployed by Apple iTunes service.

Core Network Level Interworking
- ❑ Interworking achieved through the 3GPP core network
- ❑ Defined by 3GPP Release 15/16
- ❑ **Focus of this presentation**

RAN Level Interworking
- ❑ Interworking achieved within the RAN
- ❑ LWA and LWIP for 3GPP 4G
- ❑ Not defined for 3GPP 5G system

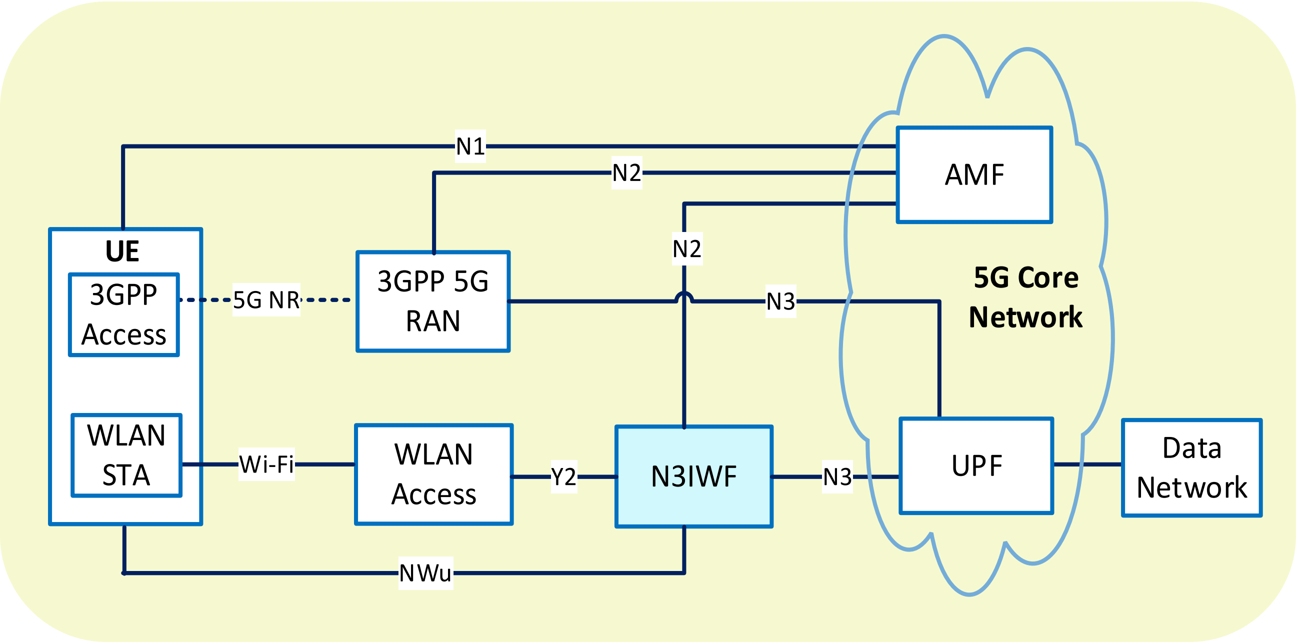
WLAN and 5G Integration Architecture

- 3GPP 5G architecture supports UE connecting to 5G core network over WLAN access, without requiring primary connectivity over cellular access
- 5G supports WLAN access integration at the core network level through gateway functions (N3IWF, TNGF and TWIF) for untrusted and trusted WLAN
  - PLMN operator makes the decision on whether a WLAN network is considered trusted or untrusted based on security features of WLAN access and/or other reasons
  - UE may discover trust relationship for WLAN networks (e.g. over ANQP) or may be configured with trusted WLAN networks
- 5G core is designed to be access neutral - gateway functions for WLAN integration interface with the 5G Core using same N2/N3 interfaces as used by the 3GPP access
- 5G has adopted EAP based authentication framework, similar to Wi-Fi, for UE authentication with 5G core
- 5G signaling and user data are transported over IPsec tunnels established between UE and gateway functions over WLAN

PLMN: Public Land Mobile Network ANQP: Access Network Query Protocol

Untrusted WLAN Integration with 5G Core

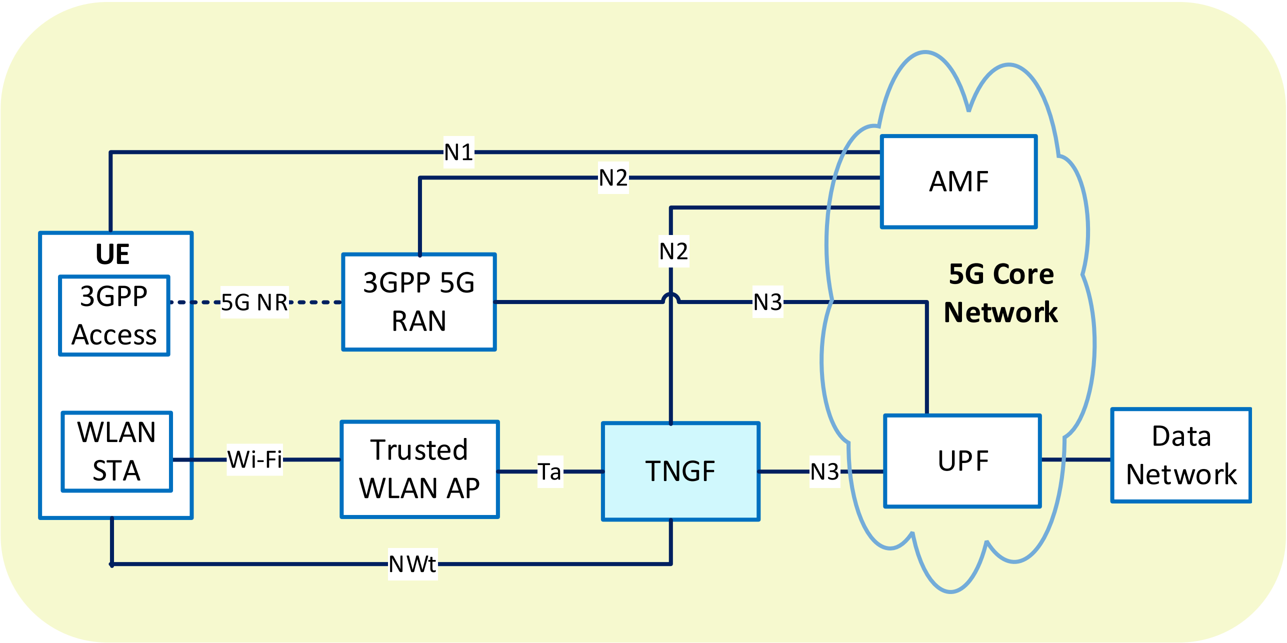
- Untrusted WLAN access is integrated with the 5G Core via N3IWF gateway function
- N3IWF interfaces with 5G core over N2/N3 interfaces, used for 3GPP access
- N3IWF and WLAN access interface through generic IP transport over Y2
- NWu establishes IPsec security associations (SAs) between UE and N3IWF for secure transport of 5G NAS signaling and user data
- IPsec SAs over NWu apply both encryption and integrity protection for 5G signaling and user data



N3IWF: Non-3GPP Interworking Function
AMF: Access and Mobility Management Function
UPF: User Plane Function

Trusted WLAN Integration with 5G Core (1/2)

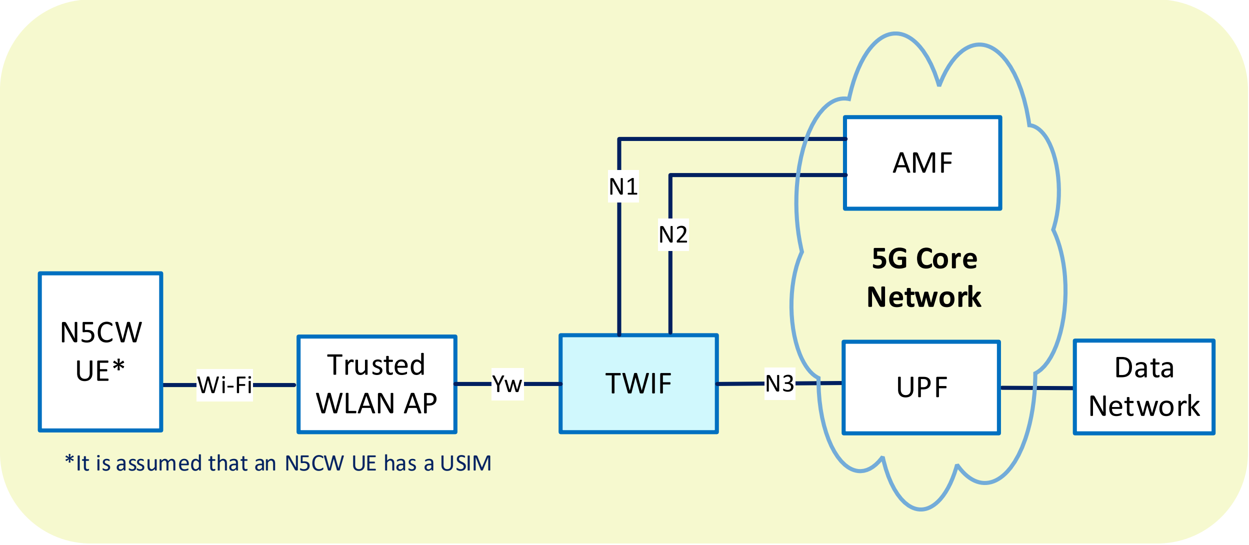
- Trusted WLAN access is integrated with the 5G core via TNGF gateway function
- Tight coupling between TNGF and trusted WLAN AP over a AAA based Ta interface
- WLAN layer-2 authentication is tied to a key from TNGF, derived based on UE authentication with the 5G Core
- NWt establishes IPsec security associations (SAs) between UE and TNGF for transport of 5G NAS signaling and user data
- IPsec SAs over NWt apply NULL encryption for signaling & user data to avoid double encryption, since WLAN layer-2 encryption is trusted



TNGF: Trusted Non-3GPP Gateway Function

Trusted WLAN Integration with 5G Core (2/2)

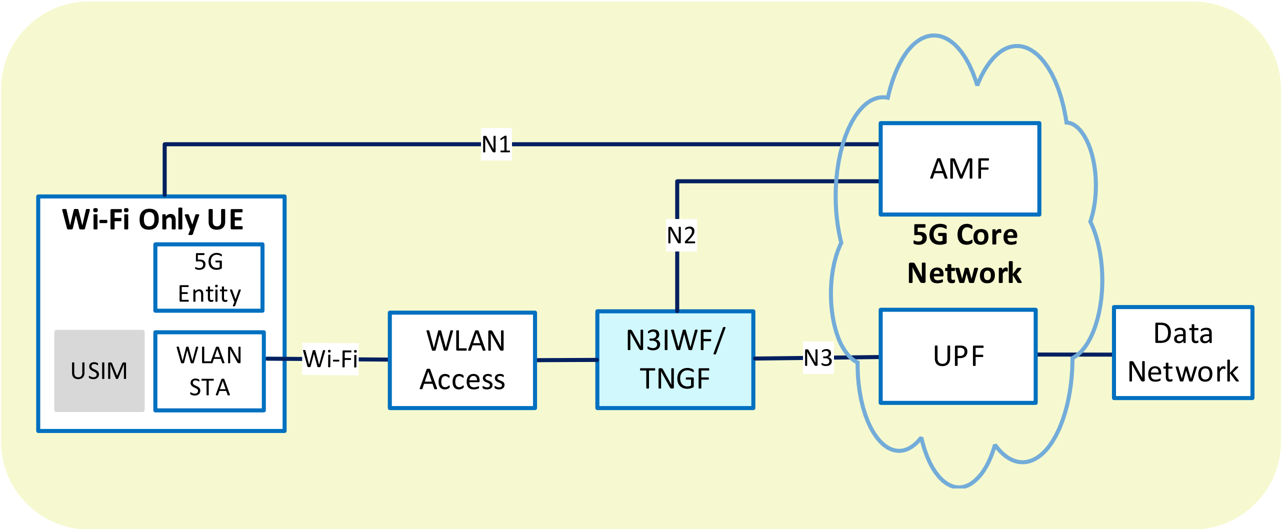
- Devices that do not support 5G NAS signaling over trusted WLAN access (N5CW devices) can still connect to 5G Core over trusted WLAN via TWIF gateway function
- TWIF implements NAS protocol on behalf of N5CW devices and performs registration and PDU session management over N1
- N5CW device has a USIM and is authenticated with 5G core using EAP-AKA' method
- Like TNGF, WLAN layer-2 authentication is tied to a key derived based on UE authentication with 5G Core
- An N5CW device may be a dual radio device operating as a 5G UE over 3GPP access (not shown for simplicity)



TWIF: Trusted WLAN Interworking Function
N5CW: Non-5G-Capable over WLAN
USIM: Universal Subscriber Identity Module
AKA: Authentication and Key Agreement

Support for Wi-Fi Only Devices

- Current 3GPP 5G architecture does not define support for Wi-Fi only devices w/o USIM
- 3GPP PLMN network only supports SIM based authentication methods (EAP-AKA’ and 5G-AKA), which require USIM on the UE
- A Wi-Fi only UE with USIM supporting 5G NAS and user plane functionality over WLAN can connect to 5G core via N3IWF/TNGF
- An N5CW Wi-Fi only device is also required to have a USIM
- However, since most Wi-Fi only devices do not include a USIM, there is a gap to be addressed



Interworking Functions

- WLAN Access Network Selection
- Registration and Authentication
- PDU Session Management
- UE Route Selection Policy (URSP)
- Access Traffic Steering, Switching and Splitting (ATSSS)
- 5G QoS Model
- User Data Transport

WLAN Access Network Selection

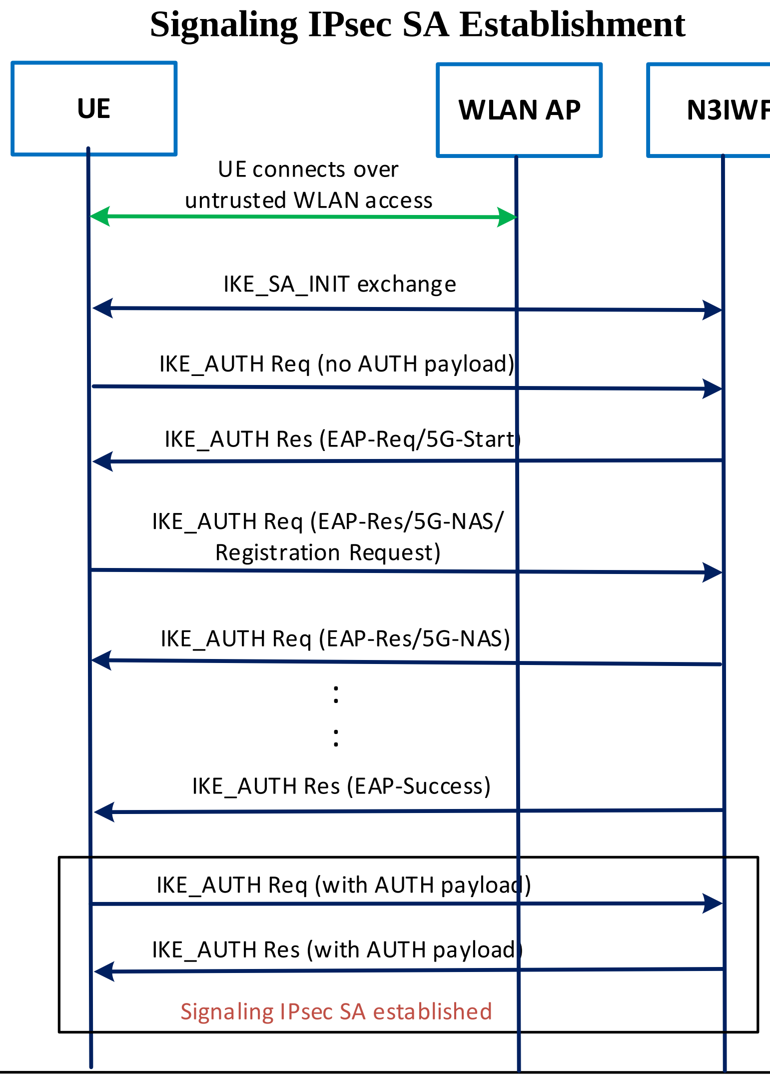
- 5G policies for WLAN network selection are provided in the Access Network Discovery and Selection Policy (ANDSP) through WLAN Selection Policy (WLANSP) rules
- WLANSP rules are used to select a preferred WLAN network for untrusted connectivity to 5G Core via N3IWF
- WLANSP rules apply only when a WLAN access can not be selected based on user preferences
- UE may decide to establish trusted WLAN connectivity based on UE configurations, capabilities, implementation procedure and types of WLAN network discovered
- To connect to trusted WLAN access, UE follows following steps:
  - ❑ Over ANQP, UE queries PLMNs with which trusted 5G connectivity is supported by WLAN networks
  - ❑ UE then selects a PLMN to connect from the list of available PLMNs
  - ❑ Finally, the UE selects a WLAN network providing trusted 5G connectivity to the selected PLMN, using WLANSP rules to prioritize and select a preferred WLAN network
- Different WLAN network selection policies may exist on the UE (e.g. policies from end user, device manufacturer, applications, operator and enterprise IT) and interworking across these policies may be device OEM specific

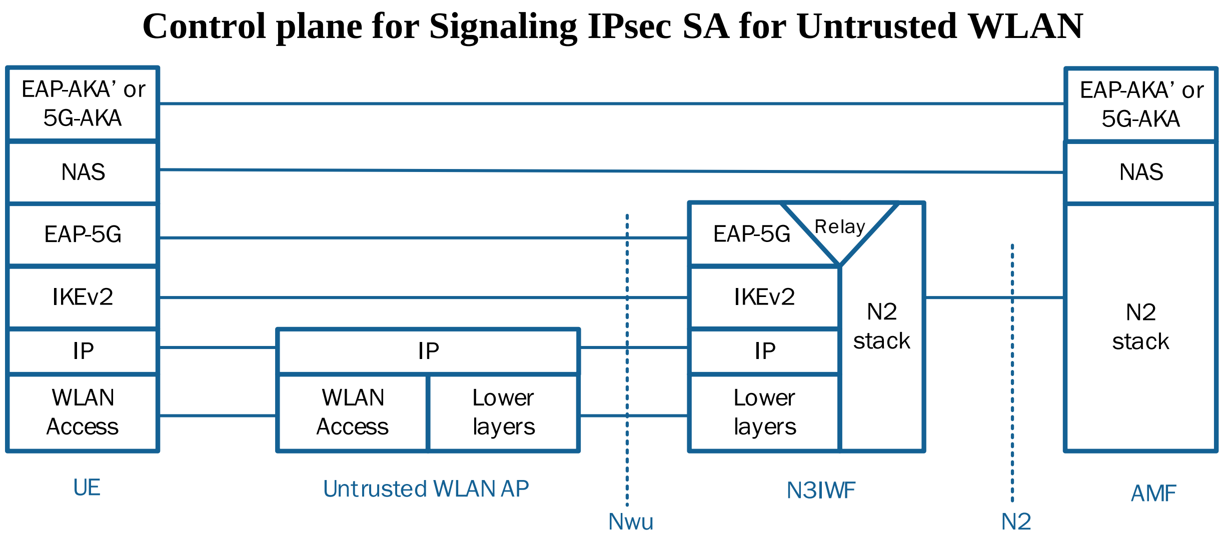
Registration and Authentication

- UE registration with the 5G core over WLAN access is based on the registration procedure defined over the 3GPP access
- A vendor specific EAP-5G method is defined by 3GPP to encapsulate NAS registration messages between UE and N3IWF/TNGF
- UE authentication over WLAN access is done using EAP-AKA’ or 5G-AKA authentication method, like done over the 3GPP access
- A signaling IPsec ESP security association (SA) is established between UE and N3IWF/TNGF during registration using IKEv2 protocol for transport of NAS messages over WLAN access
- For untrusted WLAN, UE 5G core authentication happens after WLAN connectivity and authentication is completed
- For trusted WLAN, WLAN layer 2 authentication is tied to the UE 5G core authentication

NAS: Non-Access Stratum, IKEv2: Internet Key Exchange Version 2

IPsec SA over Untrusted WLAN



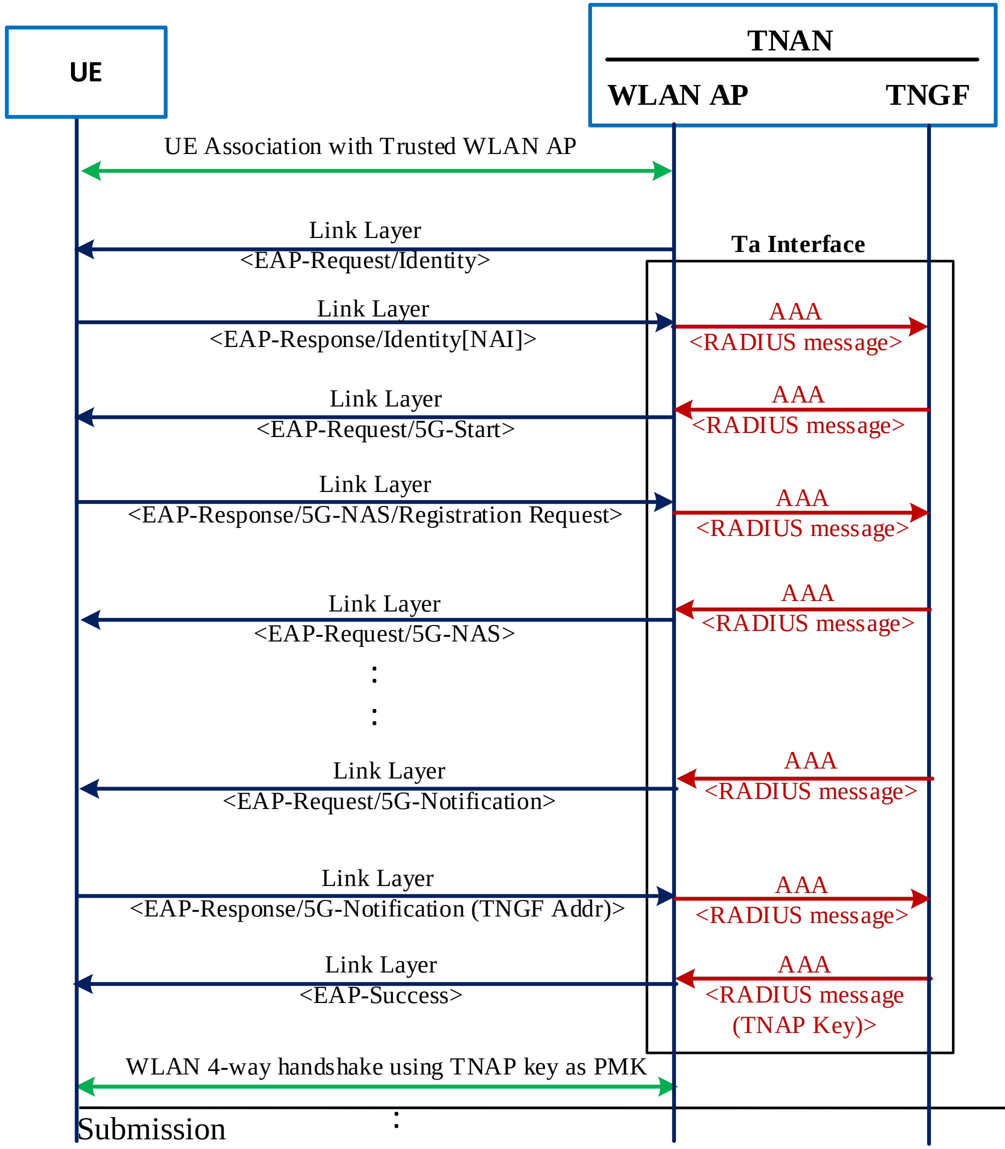


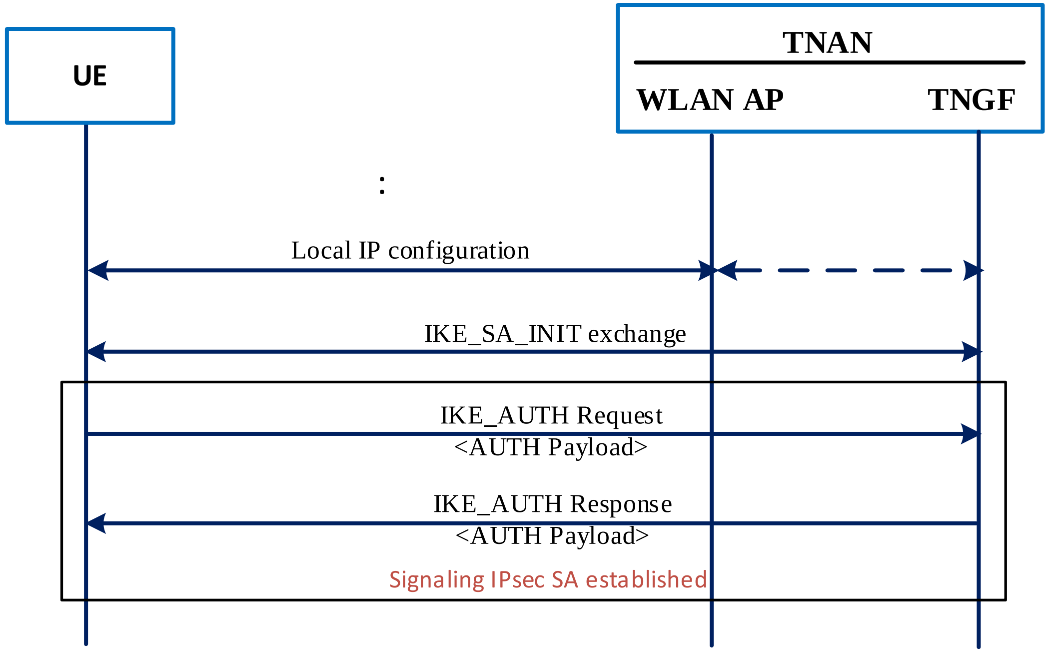
*Lower Layers represent L2/L1 for backhaul e.g. Ethernet

- First, UE associates and authenticates over untrusted WLAN access
- Next, UE 5G registration/auth is executed over IKEv2, with 5G NAS messages encapsulated over EAP-5G
- A signaling IPsec SA is established using common N3IWF key
- Signaling IPsec SA applies both encryption and integrity protection
- EAP-5G and IKEv2 protocols implemented by 3GPP access & N3IWF
- No impact to WLAN STA and AP, however this results in double encryption

IPsec SA over Trusted WLAN (1/2)

Signaling IPsec SA Establishment



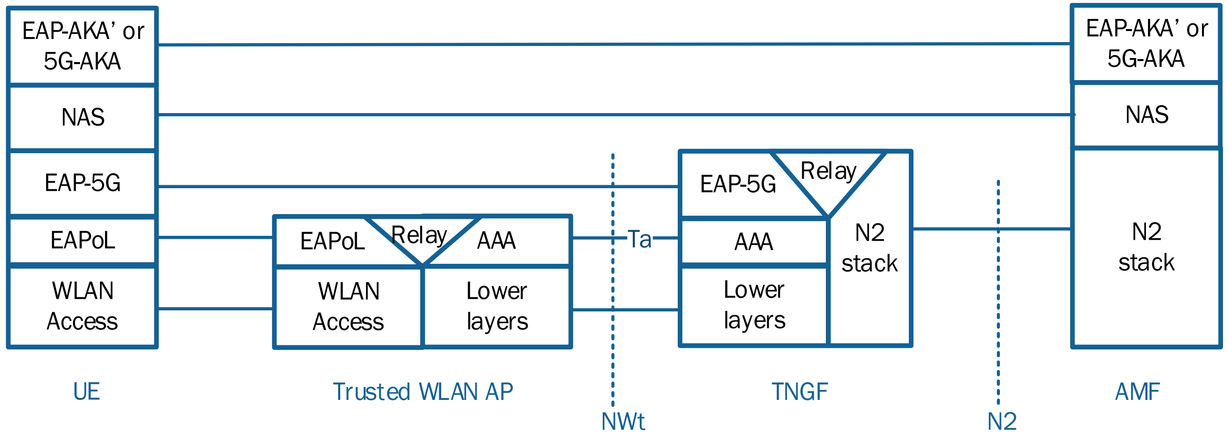


- UE establishes L2 association with trusted WLAN AP
- UE provides 5G specific NAI in EAP-Response/Identity to trigger EAP-5G session from TNGF over Ta
- After UE 5G core authentication, a TNAP key sent to WLAN AP and used as PMK for WLAN 4-way handshake
- A signaling IPsec SA is established using common TNGF key
- Signaling IPsec SA applies NULL encryption, to avoid double encryption

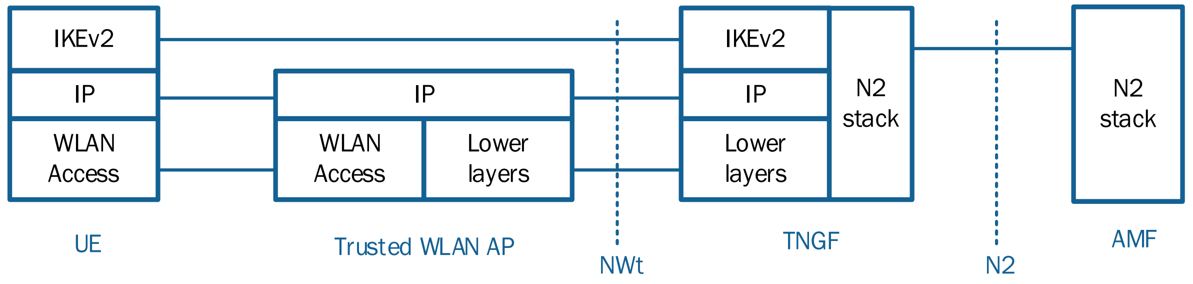
IPsec SA over Trusted WLAN (2/2)

- EAP-5G protocol is implemented as part of 3GPP Access on the UE and on the TNGF
- Support for filtering EAP-5G messages at the WLAN AP
- 5G NAS messages encapsulated over EAP-5G, then encapsulated over AAA/RADIUS protocol over Ta interface and over IEEE 802.1x/EAPoL on the Wi-Fi link
- Signaling IPsec SA is established using IKEv2 protocol

Control plane for Signaling IPsec SA for Trusted WLAN



Control plane over Trusted WLAN before UE is assigned IP address

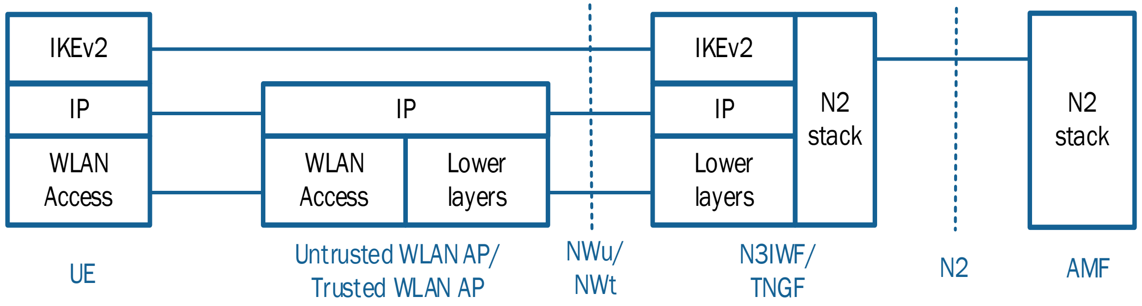


Control plane over Trusted WLAN after UE is assigned IP address

PDU Session Management

- A PDU connectivity service is supported via PDU sessions to exchange PDUs between UE and data network
- PDU session management over WLAN access is based on the procedure defined over the 3GPP access
- Over WLAN access, one or more IPsec child SAs are created using IKEv2 protocol between N3IWF/TNGF and UE to transport 5G flows user data
- N3IWF/TNGF determines the # of IPsec child SAs to establish and QoS flow(s) associated with each child SA
- Multiple QoS flows can be mapped to the same IPsec child SA for a PDU session
- N3IWF/TNGF can associate a DSCP value with an IPsec SA, UL and DL IPsec traffic gets marked with that DSCP

Control Plane for establishment of user plane IPsec child SA



- ❑ For IPsec child SA, endpoints are 3GPP access on the UE and the N3IWF/TNGF
- ❑ No impact on the WLAN AP or STA for session management

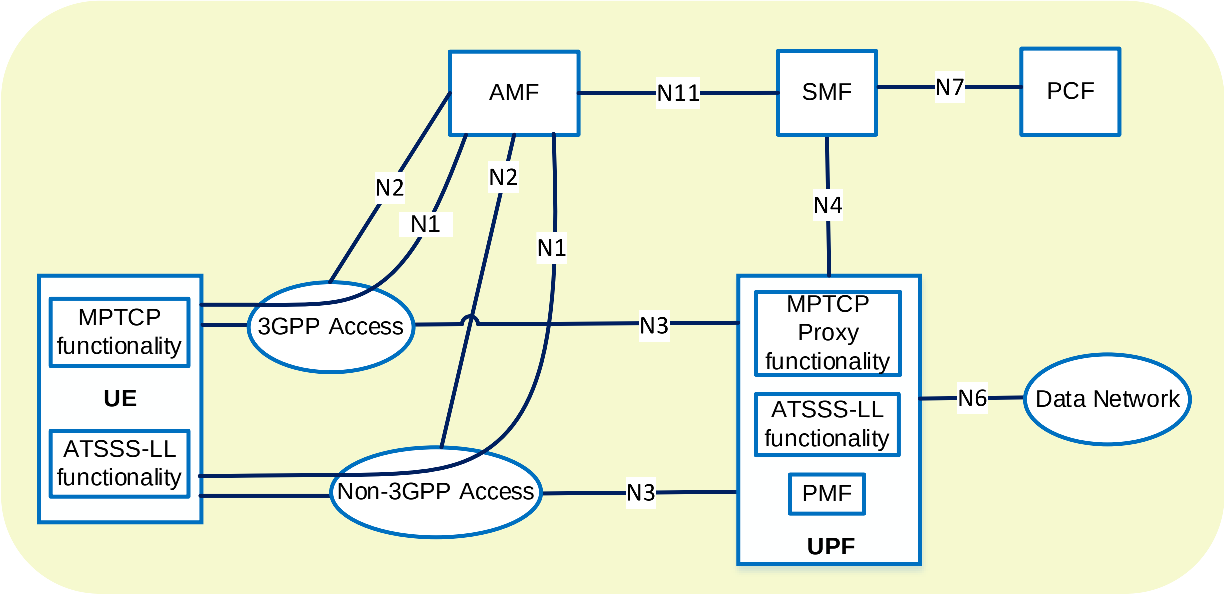
PDU: Protocol Data Unit, DSCP: Differentiated Services Codepoint

UE Route Selection Policy (URSP)

- URSP policy is used by the UE to determine how to route UL traffic for an application. Provided to the UE over 5G NAS messaging.
- UL traffic can be routed to an established PDU session, offloaded to non-3GPP access outside a PDU session, or can trigger establishment of a new PDU session (single access or multi-access)
- Each URSP rule has three main components:
  - **Rule Precedence** – to determine the priority order of the rule
  - **Traffic Descriptor** – to find the matching application for which rule applies
  - **List of Route Selection Descriptors** – to determine how the matching flow should be routed. Contains one or more Route Selection Component plus validation criteria (time window, location).
    - **Access Type preference** - 3GPP, non-3GPP or Multi-Access PDU session. For an MA PDU session, the ATSSS functionality is invoked.

Access Traffic Steering, Switching and Splitting (1/2)

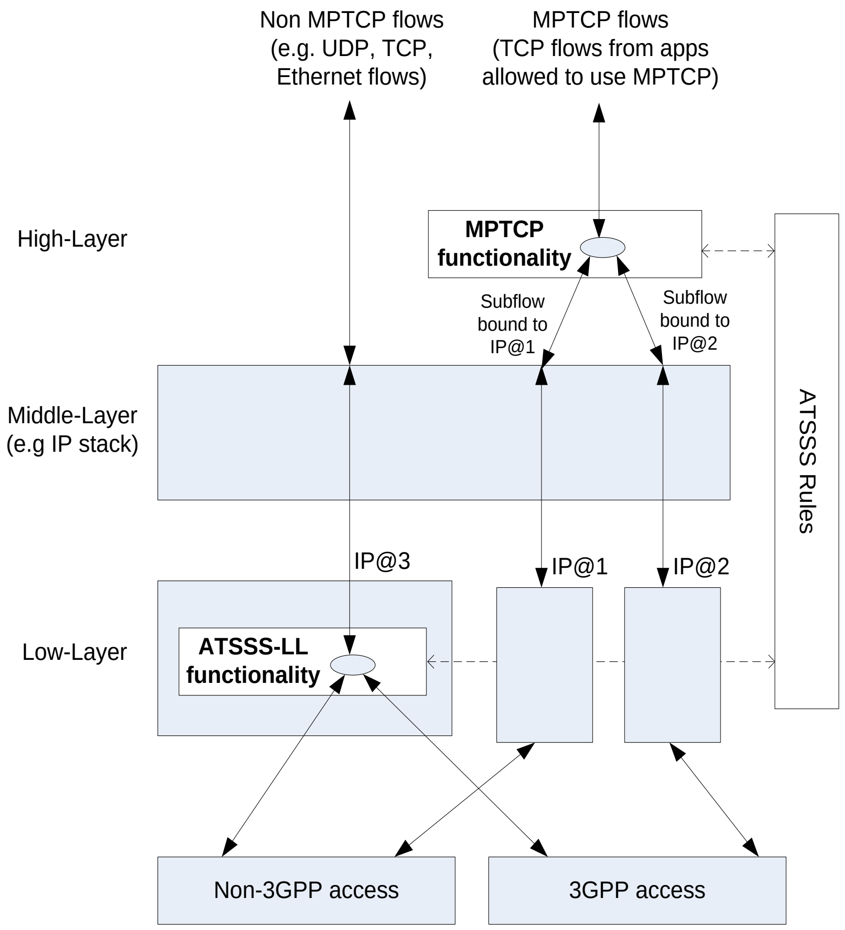
- **Support for Multi-Access PDU (MA PDU) session**
  - Enables PDU data delivery over 3GPP and WLAN access simultaneously
  - MA PDU session establishment - when UE registered over single or both access
  - When UE registered over both access, user plane resources established over both access
- **Support for two steering functionalities**
  - **MPTCP functionality** (at high layer), for TCP traffic, with MPTCP converter proxy in UPF
  - **ATSSS-LL functionality** (at low layer) for all traffic types including TCP, UDP, Ethernet traffic
- **UE/UPF may support one or more steering functionality**
  - ATSSS-LL mandatory for Ethernet PDU session



- **Support of Performance Measurement Function (PMF) for ATSSS-LL**
  - Request access specific performance measurements from UE over user-plane of 3GPP and WLAN access

Access Traffic Steering, Switching and Splitting (2/2)

- UE provides its ATSSS Capability to the network for supported steering functionalities (MPTCP and/or ATSSS-LL)
- SMF creates ATSSS rules and N4 rules based on the PCC policy
- ATSSS rules sent to the UE for UL traffic distribution, and N4 rules sent to UPF for DL traffic distribution
- If MPTCP functionality is selected, the MPTCP Proxy functionality is enabled in the UPF
- MPTCP proxy uses converter protocol (RFC 8803)
- An ATSSS container IE sent to UE:
  - ❑ ATSSS Rules
  - ❑ MPTCP proxy information
  - ❑ Link specific IP addresses (IP@1, IP@2)
  - ❑ Measurement Assistance Information for PMF reporting



ATSSS Rules

An ATSSS rule includes following parts:

- **Rule Precedence** – to determine the priority order of the rule
- **Traffic Descriptor** – to identify matching user data traffic to determine when ATSSS rule applies
- **Steering Mode** – to specify the traffic distribution policy over 3GPP and non-3GPP access.
    - Active Standby**:** Steer traffic on the Active access, when the Active access becomes unavailable switch to Standby access
    - Smallest Delay**:** Steer traffic to the access with smallest RTT delay
    - Load Balancing**:** Split traffic across both access based on percentage specified
    - Priority Based**:** Steer traffic to high-priority access, until that access gets congested. Then steer traffic also to the low-priority access
- **Steering Functionality** – to specify whether the MPTCP or the ATSSS-LL functionality should be used to steer the matching traffic

Current ATSSS feature does not require any enhancements in WLAN STA or WLAN AP.

5G QoS Model (1/2)

- The 5G QoS model, as used over the 3GPP access, is also followed when UE accesses the 5G core over WLAN access
- The **QoS Flow** (identified by QFI) is the finest granularity of QoS differentiation within the PDU session, both for single access and multi-access (MA) PDU sessions
- During PDU session establishment, one or more QoS Flows get associated with the PDU session based on the binding of PCC rule to a QoS Flow
- User plane traffic with the same QFI for a PDU session receives same traffic forwarding treatment within the access network
- A QoS Flow is not associated with specific access for MA PDU session - same QoS is supported when the flow traffic is distributed over 3GPP access and/or WLAN access
- A QoS flow can be either guaranteed bit rate flow (**GRB QoS Flow**) or non-guaranteed bit rate flow (**Non-GBR QoS Flow**)

5G QoS Model (2/2)

- **5G QoS Flow –** A QoS flow carried over WLAN access has following associated information:
  - **QoS Profile** – specifies QoS parameters for the QoS flow. Provided to N3IWF/TNGF over N2 as part of PDU session management. Used by N3IWF/TNGF to map QoS flows to IPsec child SAs.
  - **QoS Rules** – specifies Packet Filter set to map UL traffic to QoS flows within a PDU session. Either signaled to/derived by UE by applying Reflective QoS control on DL traffic.
  - **QoS Flow Description** – specifies QoS parameters for the QoS flows to the UE. These can be used by the UE to provide QoS differentiation for the indicated QoS flow.
  - **5G_QOS_INFO Notify Payload** – contains QoS specific parameters within the Create_Child_SA request sent to the UE to establish an IPsec child SA over WLAN access.
  - **Packet Detection Rules** (PDR) – specifies Packet Filter set. Provided to the UPF and used to map DL user traffic to N3/N9 core network tunnel with 3GPP or WLAN access
- **5G QoS Characteristics** – A 5QI (5G QoS Identifier) value identifies a set of QoS characteristic associated with a QoS flow. Used within the 5G Core, RAN and UE for QoS treatment.

5G QoS Characteristics

- **Standardized 5QI values** and associated QoS characteristics are defined for frequently used services for GBR, Delay-critical GBR and Non-GRB resource types
- Dynamically assigned 5QI values and associated characteristics can be defined for services which can not use standardized 5QI values

QoS Characteristic	Description
Resource Type	Indicates the GBR, Delay-critical GBR or Non-GBR resource type for a QoS Flow.
Priority Level	Indicates a priority in scheduling resources among QoS Flows. The lowest Priority Level value corresponds to the highest priority.
Packet Delay Budget (PDB)	Defines an upper bound for the time that a packet may be delayed between the UE and the UPF.
Packet Error Rate	Defines an upper bound for a rate of non-congestion related packet losses. Same in UL and DL. Used to determine appropriate link layer protocol configurations in 3GPP access network.
Averaging Window	Represents the duration over which the GFBR and MFBR shall be calculated.
Maximum Data Burst Volume (MDBV)	MDBV is applicable only for Delay-critical GBR resource type. It denotes the largest amount of data that the 5G-AN is required to serve within a period of 5G-AN PDB.

5G QoS Parameters

QoS Profile parameters

5G QoS Identifier (5QI)	
5G QoS Characteristics (optional)	
Allocation and Retention Priority (ARP)	
For Non-GBR QoS Flow only	
Reflective QoS Attribute (RQA)	
For GBR QoS Flow only	
Guaranteed Flow Bit Rate (GFBR) - UL and DL	
Maximum Flow Bit Rate (MFBR) - UL and DL	
Notification Control	

QoS Flow Description parameters

QoS Flow Identifier (QFI)	
5G QoS Identifier (5QI)	
For GBR QoS Flow only	
Guaranteed Flow Bit Rate (GFBR) - UL and DL	
Maximum Flow Bit Rate (MFBR) - UL and DL	
Averaging Window	

QoS Rule parameters

QoS Flow Identifier (QFI)
QoS Rule Identifier (QRI)
Default QoS rule indication
Packet Filter Set
Precedence Value

5G_QOS_INFO Notify Payload parameters

PDU Session ID
QoS Flow Identifier(s)
DSCP value
Default Child SA indication
Additional QoS Information

- N3IWF and TNGF map QoS flows to IPsec child SA in an implementation specific way
- If multiple flows mapped to same IPsec SA, then TNGF determines QoS characteristics and/or parameters of the aggregated flow
- QoS parameters sent to UE in 5G_QOS_INFO Notify payload as part of the Create_Child_SA request
- TNGF **may** reserve WLAN access resources based on QoS profile
- UE may reserve WLAN access resources based on QoS parameters

User Data Transport

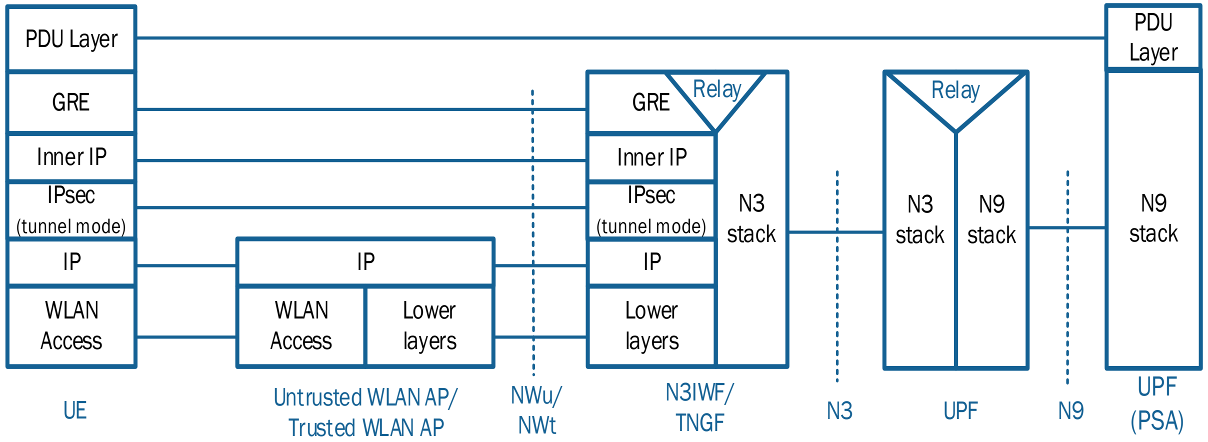
Uplink User Data Transport:

- UL data is sent over an IPsec child SA associated with the matching QoS flow/PDU session per QoS Rules
- UE encapsulates the UL data inside a GRE packet, with GRE header carrying the QFI
- GRE packet gets encapsulated into an IP packet and sent to N3IWF/TNGF over selected IPsec child SA in tunnel mode
- For UL data over MA PDU session, ATSSS rules are applied

Downlink User Data Transport:

- UPF maps DL data to a QoS Flow per packet filters in PDRs
- UPF includes QFI and RQI in the encapsulation header over N3
- N3IWF/TNGF uses the QFI/PDU session to find the associated IPsec child SA for sending DL user data
- N3IWF/TNGF encapsulates the DL packet into a GRE packet, with GRE header carrying the QFI and RQI
- GRE packet is encapsulated into an IP packet and sent to UE over the selected IPsec child SA in tunnel mode

User Plane protocol over WLAN Access



If a DSCP value is associated, then the IP packets for the IPsec child SA are marked with that DSCP value

GRE: Generic Routing Encapsulation, QFI: QoS Flow Identifier, RQI: Reflective QoS Indicator

Interworking Challenges and Gaps

Technical challenges and gaps related to enabling interworking between IEEE WLAN and 3GPP 5G system are identified in three main areas:

- **Trusted WLAN Integration**
- **End-to-end QoS Support**
- **Support for Wi-Fi Only Devices w/o USIM**

Trusted WLAN Integration

- Involves tight coupling between WLAN AP & TNGF/TWIF gateway functions on the network side and between 3GPP Access and WLAN STA on the UE

Following capabilities needed within the WLAN domain

WLAN Access Network
- Standardize AAA based Ta and Yw interfaces. Considered outside of 3GPP scope.
- Support TNGF and/or TWIF function

ANQP Server
- Advertise list of PLMNs with which trusted 5G connectivity is supported via TNGF or TWIF in the '3GPP Cellular Network information'

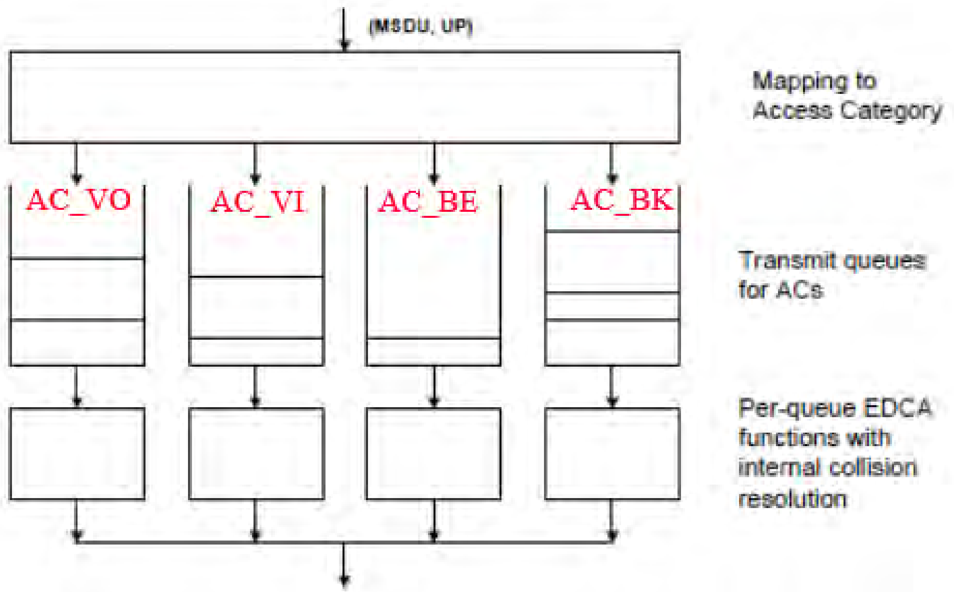
WLAN Access Point
- Support Ta and Yw interfaces
- Support invoking Ta based on 3GPP specific NAI
- Support filtering EAP-5G protocol messages
- Support using TNAP key from TNGF as PMK for the 802.11 4-way handshake

WLAN STA
- Discover PLMN lists over ANQP, send to 3GPP access
- Provide 3GPP specific NAI for UE identity for access via TNGF
- Provide unique UE NAI for access via TWIF
- Support EAP-5G messages exchange with 3GPP access on the UE

End-to-End QoS Support - Background

WLAN QoS Management:

- 802.11 **EDCA QoS scheme** provides prioritized contention-based access and is the most widely adopted WLAN QoS scheme
  - EDCA supports 8 User Priorities (UP) which get mapped to 4 QoS Access Categories (AC) for background, best effort, video and voice traffic (AC_BK, AC_BE, AC_VI, AC_VO)
  - Differentiated QoS achieved with different AIFS (Arbitration Interframe Space) and CW (Contention Window) for each AC
  - Admission control for QoS traffic streams per AC using ADDTS Request/Response with TSPEC (traffic specification) and TCLAS (traffic classification) elements
  - No guarantees can be provided on throughput, latency etc. Only priority-based bandwidth allocation provided based on ACs
- Support for mapping data packets to 802.11 UP based on DSCP marking in the IP header



QoS Differentiation for 5G Flows

- To satisfy end-to-end QoS requirements, it is important to provide QoS differentiation for 5G flows within WLAN access using EDCA QoS scheme
- Three possible approaches for QoS differentiation over WLAN access:

DSCP Marking based QoS Mapping
- QoS differentiation based on DiffServ DSCP marking in IP header for UL and DL user data
- Applicable for both untrusted and trusted WLAN integration

Device centric QoS Management based on IPsec SA
- QoS differentiation based on identifying and prioritizing IPsec child SAs carrying 5G flows
- WLAN STA initiates QoS management using EDCA admission control procedure
- Applicable for both untrusted and trusted WLAN integration

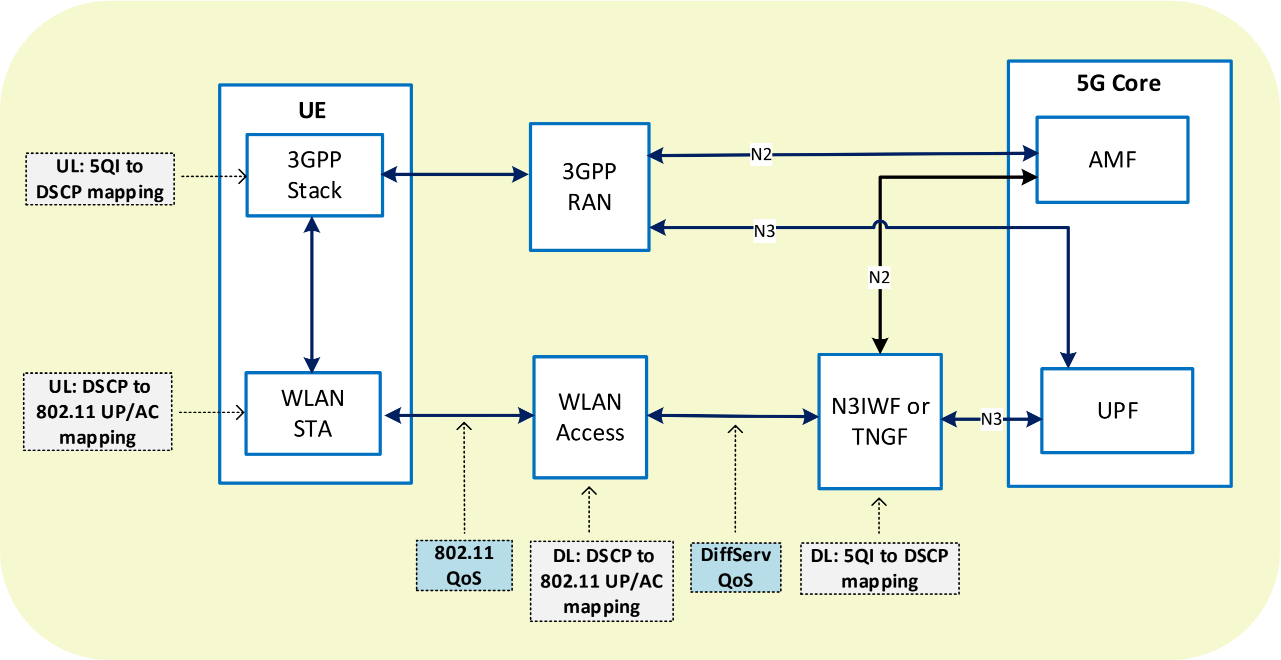
Network centric QoS Management based on IPsec SA
- QoS differentiation based on identifying and prioritizing IPsec child SAs carrying 5G flows
- WLAN AP initiates QoS management using AP-initiated procedure for EDCA admission control
- Applicable for trusted WLAN integration only

DSCP Marking Based QoS Mapping

- DSCP marking gets mapped to 802.11 UP/AC on WLAN AP (for DL) and STA (for UL)
- WLAN AP can provide 3GPP network specific DSCP to UP mapping to the STA
- Requires 5QI to DSCP mapping to be done at the N3IWF/TNGF (for DL) and at the UE (for UL)

Gaps and enhancements needed:

- ❑ Define standardized 5QI values to DSCP mapping
- ❑ Support tagging 5G user data packets with appropriate DSCP value per defined mapping
- ❑ Define 3GPP specific mapping between updated set of DSCP values to 802.11 User Priorities



QoS Differentiation Based on IPsec SA (1/2)

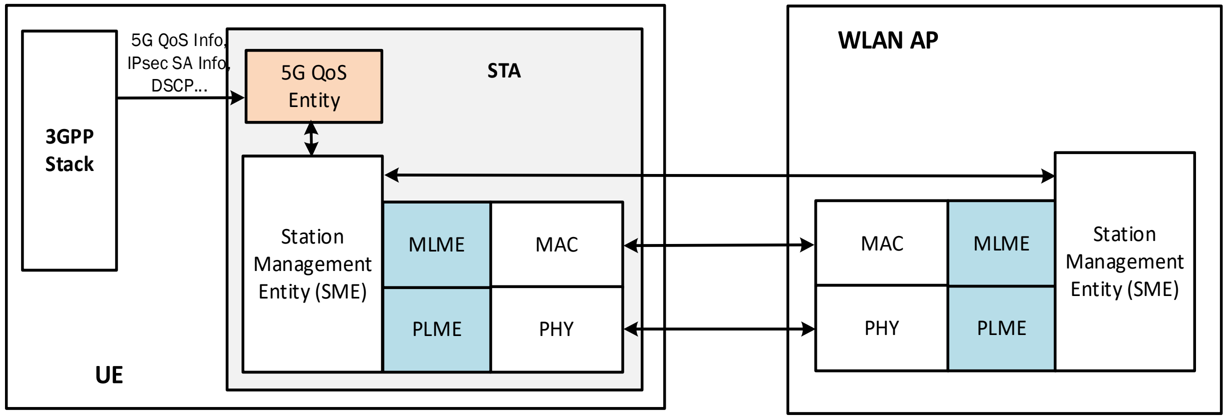
- 5G QoS information is sent to WLAN domain (STA or AP)
- **5G QoS Information:** 5G QoS characteristics and parameters, IPsec SA info for child SAs (UL and DL), DSCP
- **IPsec SA:** Uniquely identified by SPI (Security Parameter Index), destination IP address and security protocol
- 5G QoS entity maps 5G QoS characteristics/parameters to 802.11 TSPEC, creates TCLAS from the IPsec SA info

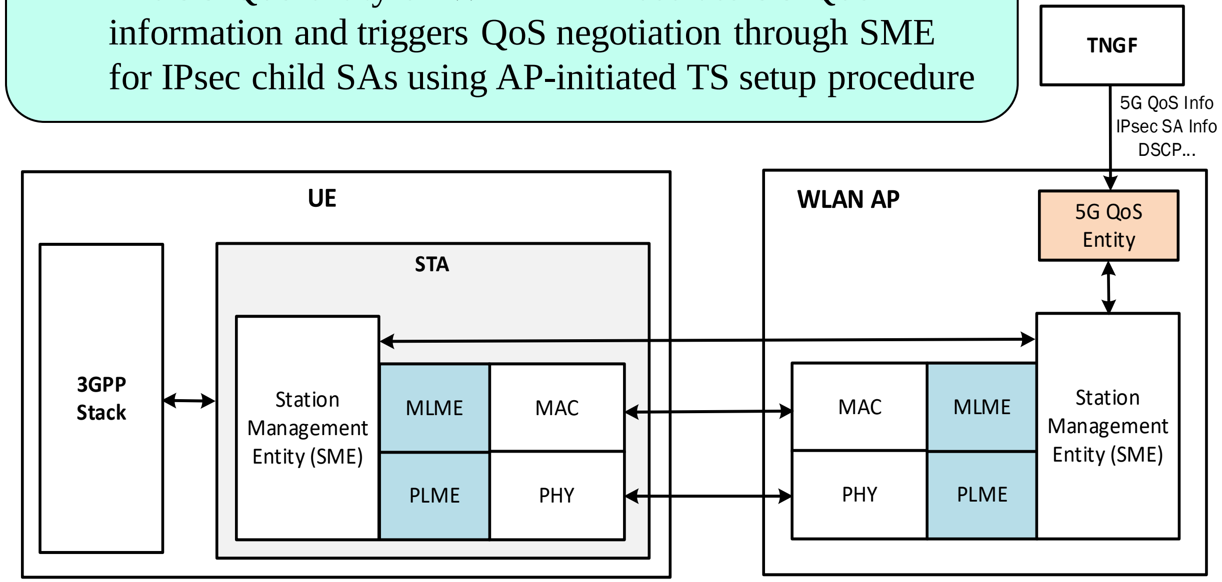
Device centric approach:

- ❑ The 5G QoS entity on STA receives 5G QoS information and triggers QoS negotiation through SME for IPsec child SAs using Non-AP-initiated TS Setup procedure

Network centric approach:

- ❑ The 5G QoS entity on WLAN AP receives 5G QoS information and triggers QoS negotiation through SME for IPsec child SAs using AP-initiated TS setup procedure





QoS Differentiation Based on IPsec SA (2/2)

Following capabilities needed within WLAN domain

N3IWF, 3GPP Access, TNGF

- Provide 5G QoS information to UE for flows over untrusted WLAN access as well
- Map each 5G QoS flow to separate IPsec child SA

WLAN AP (for Network Centric QoS Mgmt.)

- Define TNGF-WLAN AP interface to send 5G QoS information
- Integration with TNGF to receive 5G QoS info
- Support a 5G QoS entity for network centric QoS
- Support AP-Initiated TS setup for 5G flows

WLAN STA, WLAN AP:

- Define 5G QoS parameters to TSPEC parameters mapping for QoS TS setup. Address handling for TSPEC parameters not specified (e.g. MSDU size)
- Enhance TCLAS element to specify filtering for IPsec traffic based on IPsec SA identifiers (SPI, destination IP address and security protocol ID)
- Enhancement to provide all 5G QoS parameters to WLAN AP for resource reservation

WLAN STA

- Support 5G QoS entity for device centric QoS mgmt.

For further study:

- Evaluate how 802.11ax capabilities such as TWT scheduling, OFDMA and MU-MIMO can provide fine grain QoS granularity for 5G GBR flows
- IEEE 802.11be QoS enhancements should consider how QoS for 5G GBR flows (guaranteed bit rate, latency, PER, Max data burst volume) can be satisfied

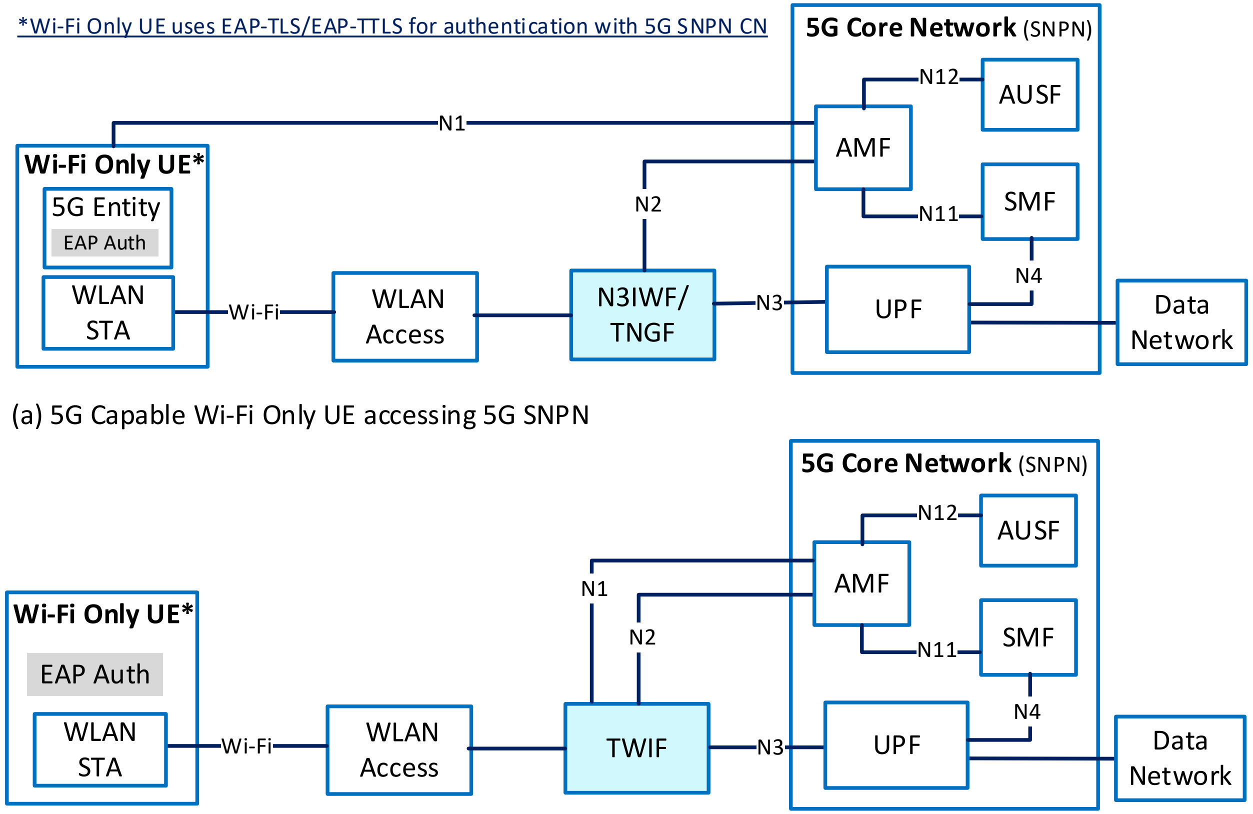
Support for Wi-Fi Only Devices w/o USIM

3GPP Gaps:

- Define support for 5G-Capable and Non-5G-Capable Wi-Fi only devices w/o USIM to access 5G Private networks (SNPN) via N3IWF/TNGF and TWIF
- Support non-IMSI based identity and EAP-TLS/ EAP-TTLS authentication for Wi-Fi only devices to access SNPN over WLAN access
- Consider requiring support for EAP-TLS/EAP-TTLS for these devices in PLMN networks

5G-Capable Wi-Fi Only UE Gaps:

- Support a 5G entity providing 5G NAS and user plane functions as defined in 3GPP
  - ❑ EAP-5G, IKEv2, IPsec/ESP and 5G NAS protocols for 5G control plane functions
  - ❑ GRE and IPsec/ESP protocols for 5G user plane transport



(a) 5G Capable Wi-Fi Only UE accessing 5G SNPN

(b) Non-5G Capable Wi-Fi Only UE accessing 5G SNPN

Technical Recommendations

- Address the gaps and enhancements identified in the three main areas to enable end-to-end system support for WLAN and 5G system interworking
- These could lead to IEEE 802.11 standard changes, deployment changes and/or new interface definitions within WLAN domain
- Some enhancements would need to be considered in 3GPP standard and could lead to Liaison sent to 3GPP

Trusted WLAN integration

- Standardize Ta and Yw interfaces
- Support TNGF, TWIF functions
- Support EAP-5G messages filtering
- Support TNAP key for WLAN 4-way authentication
- Advertise PLMN lists via ANQP…

End-to-end QoS Support

- Define 5QI to DSCP mapping
- Define 3GPP specific DSCP to 802.11 UP mapping
- Provide 5G QoS information for untrusted WLAN access
- Support IPsec SA based QoS
- Mapping of 5G QoS to TSPEC
- Enhance TCLAS for IPsec SA
- AP integration with TNGF for network centric QoS
- Map each 5G QoS flow to separate IPsec child SA…

Support for Wi-Fi only devices w/o USIM

- Support 5G-Capable and Non-5G-Capable Wi-Fi only devices over SNPN
- Support non-IMSI based identity and EAP-TLS/EAP-TTLS authentication
- For 5G-Capable Wi-Fi only UE, support 5G entity providing 5G NAS and user plane functions

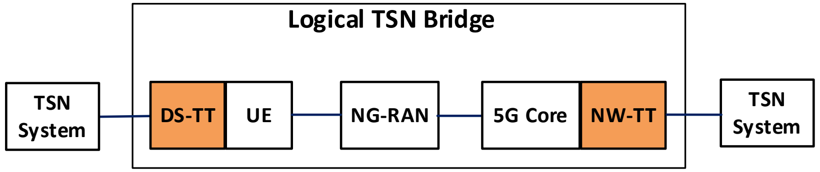
Future Work – TSN Support

802.11 TSN support

- Many 802.1 TSN protocols can be natively supported over 802.11
- Supports 802.1AS time synchronization using Fine/Timing Measurements (F/TM) capabilities
- TSN traffic classification can be achieved using VLAN tagging (802.1Q), supported by TSPEC & TCLAS
- IEEE 802.11ax features like TWT scheduling, OFDMA and MU-MIMO can be used to serve TSN requirements
- IEEE 802.11be is addressing TSN support - priority access for TSN, Multi-link operation, Multi-AP capability

5G TSN support

- 3GPP has defined architecture to integrate 5G System as a logical TSN bridge
- TSN functions confined to TSN Translator (TT) at the ingress points (AF, UPF, UE)
- Supports 802.1AS based time synchronization – with GM clock on the network side
- Supports Time-aware scheduling (IEEE 802.1Qbv)



5GS integrated as TSN Bridge

TSN Support for Integrated WLAN and 5G Network

- TSN architecture needs to be defined to integrate a WLAN and 5G integrated network with a TSN system
- Architecture needs to consider native support for many 802.1 TSN standards over IEEE 802.11
- 3GPP 5G standard should consider defining a TSN architecture for WLAN and 5G integrated network

References

- 3GPP TS 23.501: “System architecture for the 5G System (5GS); Stage 2”
- 3GPP TS 23.502: "Procedures for the 5G System; Stage 2"
- 3GPP TS 23.503: "Policies and Charging control framework for the 5G System (5GS); Stage 2"
- 3GPP TS 24.501: “Non-Access-Stratum (NAS) protocol for 5G System (5GS); Stage 3”
- 3GPP TS 24.502: “Access to the 3GPP 5G Core Network (5GCN) via Non-3GPP Access Networks (N3AN); Stage 3”
- 3GPP TS 33.501: “Security architecture and procedures for 5G system”
- 3GPP TS 24.519: “Time-Sensitive Networking (TSN) Application Function (AF) to Device-Side TSN Translator (DS-TT) and Network-Side TSN Translator (NW-TT) protocol aspects; Stage 3”
- IEEE P802.11-REVmd™/D5.0, September 2020, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications
- IEEE Std 802.11™-2016, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications
- RFC 7296, Internet Key Exchange Protocol Version 2 (IKEv2)
- RFC 2474, Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers
- RFC 2401, Security Architecture for the Internet Protocol
- RFC 8803, 0-RTT TCP Convert Protocol
- Avnu Alliance® White Paper, Wireless TSN – Definitions, Use Cases & Standards Roadmap, Version #1.0 – Mar 4, 2020

Backup

Standardized 5QI to QoS Characteristics Mapping (1/3)

For GBR resource type (TS 23.501):

5QI Value	Resource Type	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume	Default Averaging Window	Example Services
1	GBR	20	100 ms	10^{-2}	N/A	2000 ms	Conversational Voice
2		40	150 ms	10^{-3}	N/A	2000 ms	Conversational Video (Live Streaming)
3		30	50 ms	10^{-3}	N/A	2000 ms	Real Time Gaming, V2X messages. Electricity distribution – medium voltage, Process automation monitoring
4		50	300 ms	10^{-6}	N/A	2000 ms	Non-Conversational Video (Buffered Streaming)
65		7	75 ms	10^{-2}	N/A	2000 ms	Mission Critical user plane Push To Talk voice (e.g., MCPTT)
66		20	100 ms	10^{-2}	N/A	2000 ms	Non-Mission-Critical user plane Push To Talk voice
67		15	100 ms	10^{-3}	N/A	2000 ms	Mission Critical Video user plane
71		56	150 ms	10^{-6}	N/A	2000 ms	"Live" Uplink Streaming
72		56	300 ms	10^{-4}	N/A	2000 ms	"Live" Uplink Streaming
73		56	300 ms	10^{-8}	N/A	2000 ms	"Live" Uplink Streaming
74		56	500 ms	10^{-8}	N/A	2000 ms	"Live" Uplink Streaming
76		56	500 ms	10^{-4}	N/A	2000 ms	"Live" Uplink Streaming

Standardized 5QI to QoS Characteristics Mapping (2/3)

For Non-GBR resource type (TS 23.501):

5QI Value	Resource Type	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume	Default Averaging Window	Example Services
5	Non-GBR	10	100 ms	10^{-6}	N/A	N/A	IMS Signalling
6		60	300 ms	10^{-6}	N/A	N/A	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7		70	100 ms	10^{-3}	N/A	N/A	Voice, Video (Live Streaming) Interactive Gaming
8		80	300 ms	10^{-6}	N/A	N/A	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
9		90					
69		5	60 ms	10^{-6}	N/A	N/A	Mission Critical delay sensitive signalling (e.g., MC-PTT signalling)
70		55	200 ms	10^{-6}	N/A	N/A	Mission Critical Data (e.g. example services are the same as 5QI 6/8/9)
79		65	50 ms	10^{-2}	N/A	N/A	V2X messages
80		68	10 ms	10^{-6}	N/A	N/A	Low Latency eMBB applications Augmented Reality

Standardized 5QI to QoS Characteristics Mapping (3/3)

For Delay-Critical GBR resource type (TS 23.501):

5QI Value	Resource Type	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume	Default Averaging Window	Example Services
82	Delay Critical GBR	19	10 ms	10^{-4}	255 bytes	2000 ms	Discrete Automation
83		22	10 ms	10^{-4}	1354 bytes	2000 ms	Discrete Automation V2X messages (UE - RSU Platooning, Advanced Driving: Cooperative Lane Change with low LoA.
84		24	30 ms	10^{-5}	1354 bytes	2000 ms	Intelligent transport systems
85		21	5 ms	10^{-5}	255 bytes	2000 ms	Electricity Distribution- high voltage V2X messages (Remote Driving.
86		18	5 ms	10^{-4}	1354 bytes	2000 ms	V2X messages (Advanced Driving: Collision Avoidance, Platooning with high LoA.

5GS-WLAN Interworking Model and QoS management

Date: 2020-10-13

Authors:

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Abstract

It is expected that WLAN should enhance data throughput for increasing data traffic needs, and WLAN interworking to 3GPP 5G system for QoS specific ATSSS applications.

This tutorial introduces WLAN interworking model to 3GPP 5G system, QoS requirements and management for Non-GBR or GBR traffic which is referred from IEEE 802.11 AANI technical report “draft technical report on interworking between 3GPP 5G network and WLAN(IEEE 802.11-20/0013r5)”.

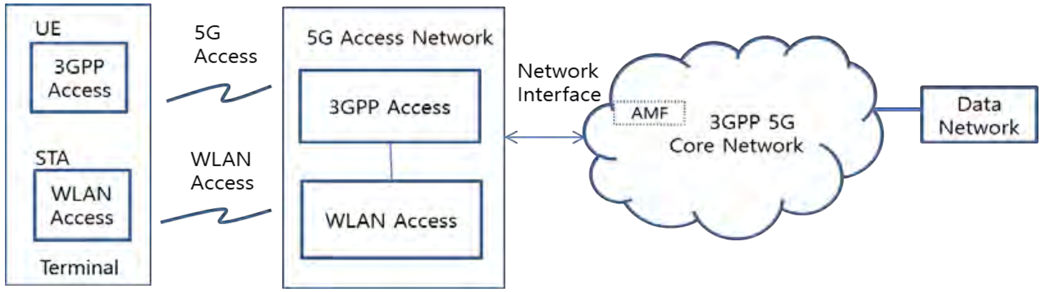
- ATSSS: Access Traffic Steering, Switching & Splitting
- GBR : Guaranteed Bit Rate.

● WLAN Interworking Types : Tightly coupled or Loosely coupled

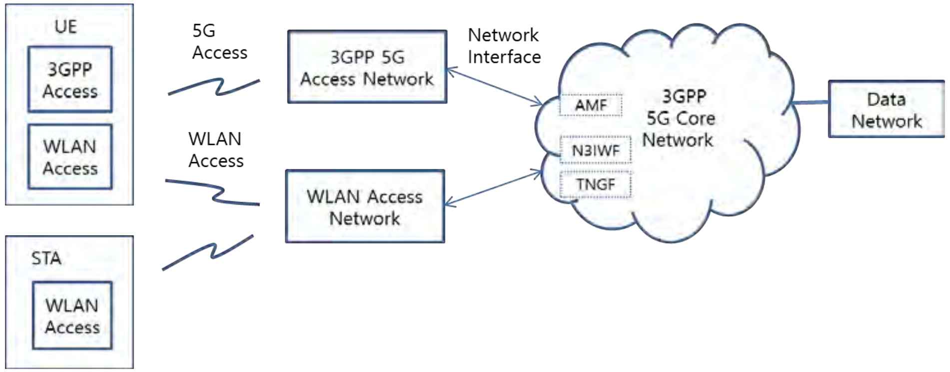
- The tightly coupled interworking type assumes that functional entities of the terminal and the two access networks are combined together and connect to 3GPP core network thus allowing a co-located 3GPP Access Network and a WLAN Access. This type is RAN level interworking.

- The loosely coupled interworking type assumes that 3GPP and WLAN access networks operate independently and may be either co-located or be separate. This type is CN level Interworking and may have trusted or untrusted non-3GPP interworking.

- There are two type of terminals: UE and STA, STA only.



Tightly coupled interworking reference model between 5G core network and WLAN(IEEE 802-11-20/0013r5)

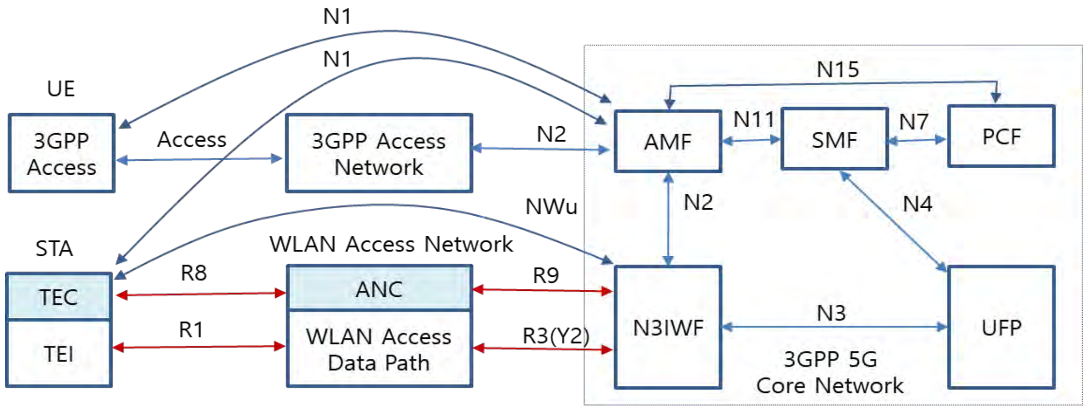


Loosely coupled interworking reference model between 5G core network and WLAN(IEEE 802-11-20/0013r5)

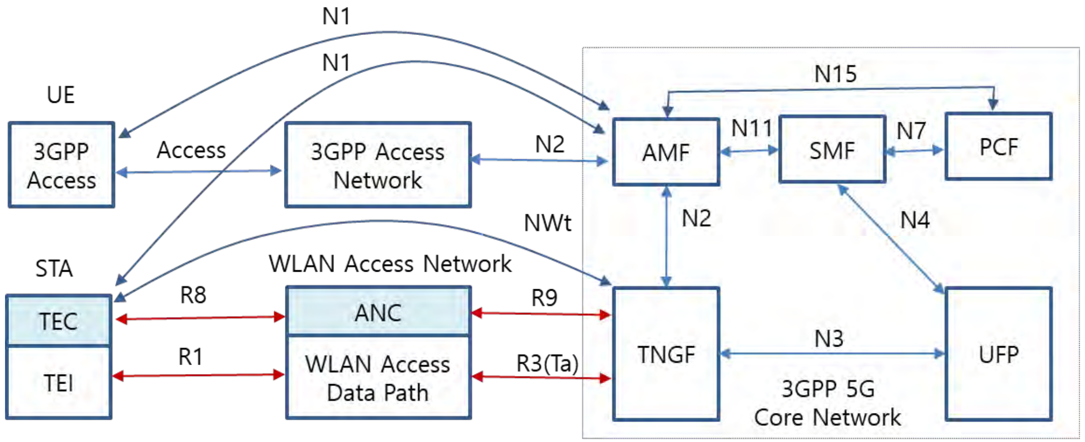
● WLAN Interworking Functional Model in 5G System

- WLAN interworking function model consists of UE/STA terminal, 3GPP/WLAN access network and 3GPP core network.

- In the WLAN domain, R1 and R3 interfaces support the data flow via the PHY and MAC layers of STA and WLAN access network. In addition to the R1 and R3 interfaces, R8 and R9 control and management interfaces are considered to provide QoS mapping and MAC scheduling.



Untrusted WLAN interworking reference model with 5G core network (IEEE 802-11-20/0013r5)



Trusted WLAN interworking reference model with 5G core network (IEEE 802-11-20/0013r5)

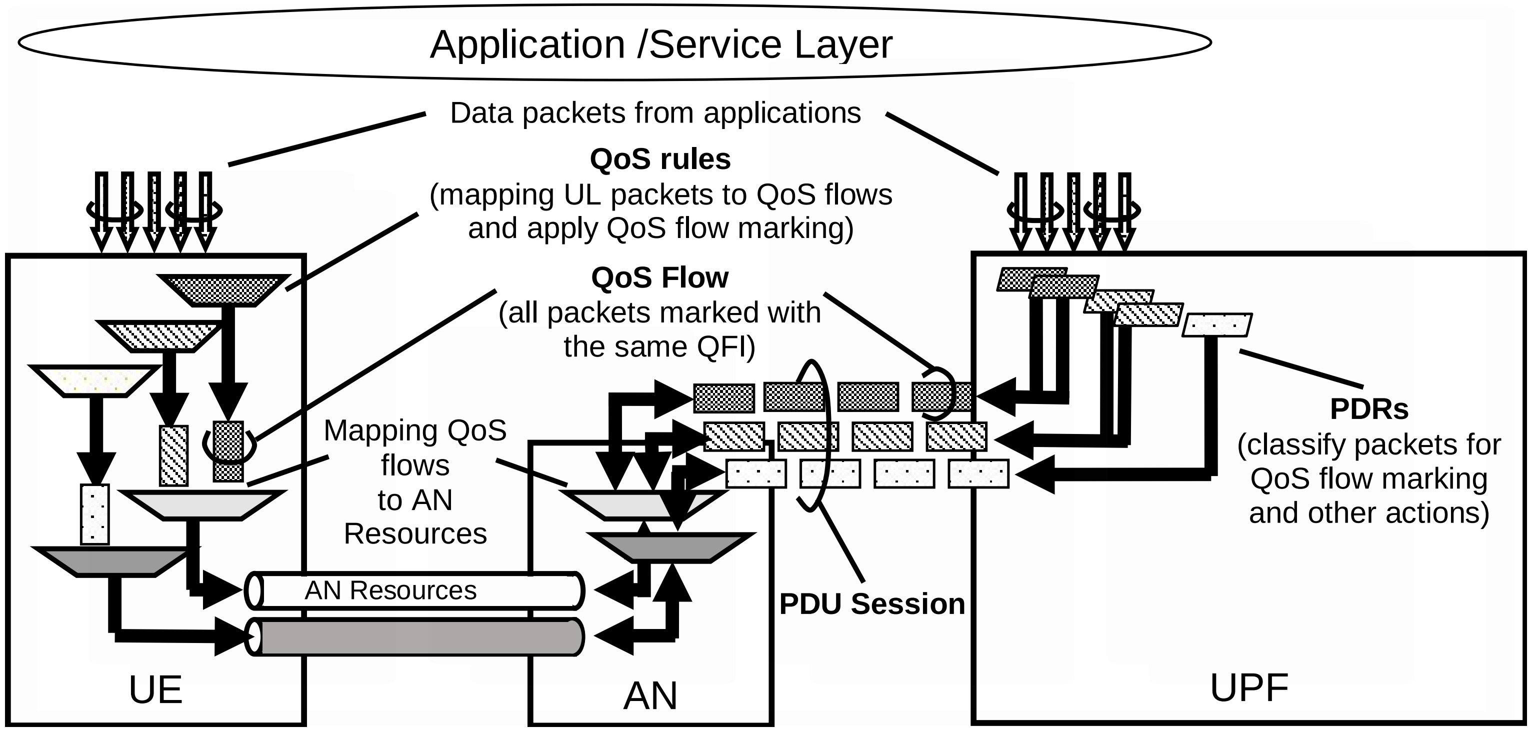
- **QoS Characteristics in GBR and delay critical GBR**

- It is necessary that GBR flows are supported by the WLAN in both directions, e.g. non-AP STA to AP and AP to non-AP STA.

Resource Type	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume	Default Averaging Window	Example Services
GBR	20	100 ms	10^{-2}	N/A	2000 ms	Conversational Voice
	40	150 ms	10^{-3}	N/A	2000 ms	Conversational Video (Live Streaming)
	30	50 ms	10^{-3}	N/A	2000 ms	Real Time Gaming, V2X messages Electricity distribution – medium voltage, Process automation - monitoring
	50	300 ms	10^{-6}	N/A	2000 ms	Non-Conversational Video (Buffered Streaming)
	7	75 ms	10^{-2}	N/A	2000 ms	Mission Critical user plane Push To Talk voice (e.g., MCPTT)
	20	100 ms	10^{-2}	N/A	2000 ms	Non-Mission-Critical user plane Push To Talk voice
	15	100 ms	10^{-3}	N/A	2000 ms	Mission Critical Video user plane
	56	150 ms	10^{-6}	N/A	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238 [y])
	56	300 ms	10^{-4}	N/A	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238 [y])
	56	300 ms	10^{-8}	N/A	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238 [y])
	56	500 ms	10^{-8}	N/A	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238 [y])
	56	500 ms	10^{-4}	N/A	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238 [y])
Delay Critical GBR	19	10 ms	10-4	255 bytes	2000 ms	Discrete Automation (see TS 22.261 [x])
	22	10 ms	10-4	1354 bytes	2000 ms	Discrete Automation (see TS 22.261 [x])
	24	30 ms	10-5	1354 bytes	2000 ms	Intelligent transport systems (see TS 22.261 [x])
	21	5 ms	10-5	255 bytes	2000 ms	Electricity Distribution- high voltage (see TS 22.261 [x])

- **3GPP QoS Model**

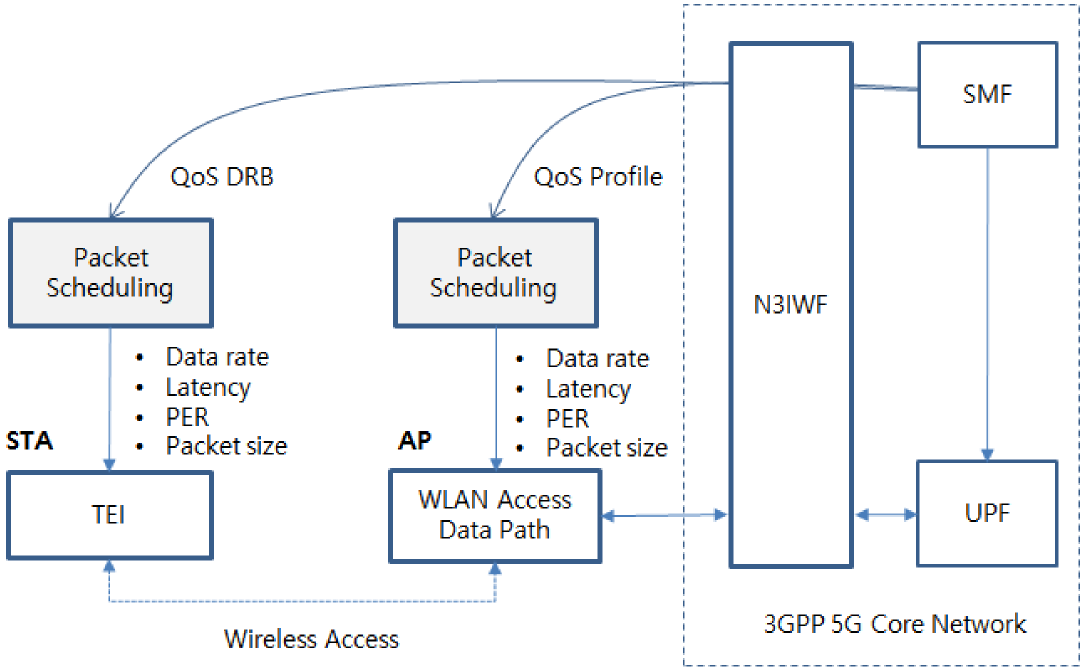
- The SMF assigns QoS profile to AN in WLAN domain with QoS Flow Identification (QFI), which defines the QoS parameters for a QoS flow in the PDU session.
- QoS flow is then mapped to AN resources for the assigned QFI.



QoS flow and mapping to AN resources in user plane for ATSSS support(3GPP TS 23.501)

WLAN QoS Mapping and Scheduling

- QoS mapping from 3GPP QoS to WLAN QoS is necessary
- Packet scheduling in STA and AP shall control MAC operation to meet required QoS
- AP QoS profile and STA DRB (Data Radio Bearers) contains service QoS identification and its parameters to define data rate, packet latency and PER value.



QoS mapping and scheduling example of WLAN(IEEE 802-11-20/0013r5)

- **Gap analysis on GBR service**

Resource Type	Services Examples	Packet Delay Budget	PER	Default Maximum Data Burst Volume	Gap Analysis of WLAN specification
GBR	Conversational Voice	100 ms	10^{-2}	N/A	. 802.11ax MAC cannot support 3GPP GBR service requirements of deterministic packet latency, PER and data rate because the current EDCA is CSMA based MAC and supports only 4 service types of best effort, back ground, voice and video by controlling TXOP, AIFSN and contention window size. ** HCCA relies on TSPECs, has a low level of implementation.* . Enhanced MAC (802.11be) should consider QoS mapping, packet scheduling and related management procedures to support GBR. And PHY and MAC should be improved to control packet latency and reliability. . QoS flow identification and service priority shall be mapped to have fine granularity of service types and QoS parameters.
	Conversational Video	150 ms	10^{-3}	N/A	
	Real Time Gaming, V2X messages	**50 ms**	10^{-3}	N/A	
	Non-Conversational Video	300 ms	10^{-6}	N/A	
	MCPTT	75 ms	10^{-2}	N/A	
	Non-MCPTT	100 ms	10^{-2}	N/A	
	MC-Video	100 ms	10^{-3}	N/A	
	"Live" Uplink Streaming	150 ms	10^{-6}	N/A	
	"Live" Uplink Streaming	300 ms	10^{-4}	N/A	
	"Live" Uplink Streaming	300 ms	$\mathbf{10^{-8}}$	N/A	
	"Live" Uplink Streaming	500 ms	10^{-8}	N/A	
	"Live" Uplink Streaming	500 ms	10^{-4}	N/A	

- **Gap analysis on Delay Critical GBR service**

Resource Type	Services Examples	Packet Delay Budget	PER	Default Maximum Data Burst Volume	Gap Analysis of WLAN specification
Delay Critical GBR	Discrete Automation	10 ms	10-4	255 bytes	. 802.11ax MAC cannot guarantee 3GPP delay critical GBR service requirements of latency, PER and guaranteed data rate. . Enhanced MAC (802.11be) should consider QoS mapping, packet scheduling and related management procedures to support GBR. And PHY and MAC should be improved to control packet latency and reliability. . 802.11bd NGV should consider ITS service requirement.
	Discrete Automation	10 ms	10-4	1354 bytes	
	Intelligent transport systems	**30 ms**	**10-5**	1354 bytes	
	Electricity Distribution- high voltage	5 ms	10-5	255 bytes	

- WLAN shall support fine granularity of QoS and priority because 5G QoS ID has 6 bits and specifies QoS parameters involving GBR (Guaranteed Bit Rate), latency and PER.

- Packet scheduling in STA and AP shall control MAC operation to meet required QoS. AP QoS profile and STA DRB (Data Radio Bearers) contains service QoS identification and its parameters

- **5GS-WLAN Interworking Considerations**

From 5GS and WLAN interworking reference model's view, IEEE 802.11 should consider adding new functional entities and signaling procedures to support interworking with the 3GPP 5G network in terms of active scanning facility, association and authentication, QoS facility.

- **QoS Management is essential !**

- QoS mapping to WLAN is necessary to support more granularity of QoS ID and parameters.
- Packet scheduling in the STA and AP should meet data rate, latency and PER.
- Timing scheduling and the adoption of a Hybrid ARQ scheme are very important.
- 802.11ax, as implemented, cannot support 3GPP GBR and delay critical GBR, and improved version (11be EHT, 11bd NGV) should consider MAC enhancement to support the service requirements.
- Time Sensitive Network(TSN) application is highly related to QoS management in WLAN domain.

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Date: 2020-10-13

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Abstract

For the IEEE 802 Plenary Electronic Session, Tutorial Session on Tuesday October 13, 2020: “802.11 WLAN and 3GPP 5G System Interworking”: Summary of the activities of the 802.11 AANI SC and the status of the technical on interworking between 3GPP 5G network & WLAN.

Outline

- **Introduction to the 802.11 AANI SC**
- **802.11 AANI SC:**
  - Performance of 802.11ax in the IMT-2020 Dense Urban and Indoor Hotspot environment
  - Status: “Technical report on interworking between 3GPP 5G network & WLAN”

802.11 AANI SC

- **"Advanced Access Network Interface Standing Committee" (AANI SC) is a committee of the 802.11 WG**
  - Chair: Joseph Levy (InterDigital)
  - Vice Chair/Secretary: Currently Vacant (prior: Roger Marks (EthAirNet Associates)
- **Ongoing Activity: Development of the "Technical Report on Interworking between 3GPP 5G Network and WLAN"**
  - Resolve all outstanding comments
  - Present the report to the 802.11 WG for endorsement
  - Generate an action plan to implement the reports recommendations
- **Previous Activity (completed work):**
  - Performance analysis of 802.11ax in the IMT-2020 Dense Urban and Indoor Hotspot environments
  - Communicated with 3GPP via Liaison Statements regarding 5G/IMT-2020 Interworking

Performance of 802.11ax in the IMT-2020 Dense Urban and Indoor Hotspot environment

- **IEEE Press Release [3]:**

  "IEEE P802.11ax™ Meets Requirements for 5G Indoor Hotspot and Dense Urban Deployments Enabling Enhanced Wireless Network Performance

  Draft standard provides a cost-effective option for 5G deployments as defined by International Telecommunications Union"

- **The Press Release was supported by the technical report: "Summary of 802.11ax Self Evaluation for IMT-2020 EMBB Indoor Hotspot and Dense Urban Test Environments" [4]**

802.11ax: IMT-2020 Indoor Hotspot environment [4]

	Metric	ITU-R Evaluation Method	Minimum Requirement	802.11ax Performance (*Source [4]*)
1	Peak data rate	Analytical	DL/UL : 20/10 Gbps	DL/UL : 20.78 Gbps [*Note 1*]
2	Peak spectral efficiency	Analytical	DL/UL : 30/15 bits/s/Hz	DL/UL : 58.01 bits/s/Hz [*Note 2*]
3	User experienced data rate	Not applicable for Indoor Hotspot	Not applicable for Indoor Hotspot	Not applicable
4	5th percentile user spectral efficiency	Simulation	DL/UL : 0.3/0.21 bits/s/Hz	DL/UL : 0.45/0.52 bits/s/Hz [*Note 3*]
5	Average spectral efficiency	Simulation	DL/UL : 9/6.75 bits/s/Hz/TRxP	DL/UL : 9.82/13.7 bits/s/Hz/TRxP [*Note 3*]
6	Area traffic capacity	Analytical	DL : 10 Mbit/s/m^2	Required DL bandwidth = 170 MHz with 3 TRxP/site. [*Note 4*]
7	Mobility	Simulation	UL : 1.5 bits/s/Hz	UL : 9.4 bits/s/Hz
8	Bandwidth	Inspection	100 MHz, scalable	20/40/80/80+80/160 MHz
9	User plane latency	Analytical	DL/UL : 4 ms	DL/UL : 80 us [*Note 5*]

notes and references in the table are in [4]

802.11ax: IMT-2020 Dense Urban environment [4]

	Metric	ITU-R Evaluation Method	Minimum Requirement	802.11ax Performance	
				Source [5]	**Source** [8]
1	Peak data rate	Analytical	DL/UL: 20/10 Gbps	DL/UL: 20.78 Gbps [*Note 1*]	Same
2	Peak spectral efficiency	Analytical	DL/UL: 30/15 bits/s/Hz	DL/UL: 58.01 bits/s/Hz [*Note 2*]	Same
3	User experienced data rate	Analytical for single band and single layer; Simulation for multi-layer	DL/UL: 100/50 Mbit/s	DL/UL: 113.6/81.6 Mbps [*Note 3*]	Same
4	5th percentile user spectral efficiency	Simulation	DL/UL: 0.225/0.15 bits/s/Hz	DL/UL: 0.71/0.51 bits/s/Hz [*Note 3*]	DL/UL: 0.49/0.327 bits/s/Hz
5	Average spectral efficiency	Simulation	DL/UL = 7.8/5.4 bits/s/Hz/TRxP	DL/UL: 10.84/8.75 bits/s/Hz/TRxP [*Note 3*]	DL/UL: 9.61/7.34 bits/s/Hz/TRxP
6	Area traffic capacity	Analytical	Not applicable for Dense Urban	Not applicable	Not applicable
7	Mobility	Simulation	UL: 1.12 bits/s/Hz	UL : 1.75 bits/s/Hz [*Note 4*]	UL : 1.54 bits/s/Hz
8	Bandwidth	Inspection	100 MHz, scalable	20/40/80/80+80/160 MHz	Same
9	User plane latency	Analytical	DL/UL : 4 ms	DL/UL : 80 us [*Note 5*]	Same

notes and references in the table are in [4]

"Technical report on interworking between 3GPP 5G network & WLAN"

- **July 2019 – a proposal was made to develop a report on:** Interworking between IEEE 802.11 WLAN and 3GPP 5G Core Network [5]
- **July 2020 - A report was developed over the year resulting in:** "Draft technical report on interworking between 3GPP 5G network & WLAN", Hyun Seo OH (ETRI), et al. [6]
  - Reviewed by the 802.11 WG in a 20 Day Comment Collection (30 July 2020) – which generated 111 comments.
  - Comment resolution is proceeding.
- **August 2020 – An alternate technical report was contributed**: "Technical report on the interworking between 3GPP 5G system and WLAN", Binita Gupta (Intel), Necati Canpolat (Intel) [7]. (Also see: "Context on 11-20-1376r0 technical report" [8])
  - The merging of content from this report is being considered in the comment resolution process.
- **Ongoing Activity – Comment Resolution/Technical Report development** [9]

References

[1] ec-16/0119r1, IEEE 802 EC 5G / IMT-2020 Standing Committee Report, Glenn Parsons (Ericsson),

[2] 11-16/1057r1, "802.11 IMT-2020/5G SC Proposal", Joseph Levy (InterDigital)

[3] IEEE Press Release: https://standards.ieee.org/news/2019/5g-indoor-hotspot-and-dense-urban-deployments.html, "IEEE P802.11ax meets the salient requirements of IMT-2020 Indoor Hotspot and Dense Urban environments", 17 Dec 2019

[4] 11-19/1284r2, "Summary of 802.11ax Self Evaluation for IMT-2020 EMBB Indoor Hotspot and Dense Urban Test Environments", Sindhu Verma (Broadcom) and Shubhodeep Adhikari (Broadcom)

[5] 11-19/1160r1, "Proposal on Interworking between IEEE 802.11 WLAN and 3GPP 5G Core Network", Hyun Seo Oh, Hanbyeog Cho (ETRI), Chang Han Oh (allRadio Co. Ltd), Si Young Heo (KT), Hyeong Ho Lee (Netvision Telecom Inc., Korea Univ.)

[6] 11-20/0013r5, "Draft technical report on interworking between 3GPP 5G network & WLAN", Hyun Seo Oh, et. al.

[7] 11-20/1376r0, "Technical report on interworking between 3GPP 5G system and WLAN", Binita Gupta (Intel), Necati Canpolat (Intel)

[8] 11-20/1472r0, "Setting context for submission 11-20/1376r0 'Technical report on the interworking between 3GPP 5G system and WLAN' ", Binita Gupta (Intel), Necati Canpolat (Intel)

[9] 11-20/1262, "CC32-AANI_Report_Comments", Joseph Levy (InterDigital)

BACK-UP SLIDES

Background on the 802.11 AANI SC

- **In response to interest and concerns regarding 5G/IMT-2020 activity in 2016: IEEE 802 formed a committee to generate a report [1] on:**
  - Costs and benefits of creating an IEEE 5G specification
  - Cost and benefits of providing a proposal for IMT-2020
- **The report generated 2 key recommended Actions:**
  - Action A – Adoption of IEEE 802 Access Network specification in multiple disparate operator networks..
  - Action B3 – IMT-2020 proposal, external proposal:
    Support development of a 3GPP proposal for IMT-2020 incorporating references to integration of IEEE 802.11 or an IEEE 802 Access Network.
- Action A led 802.1 to create the Nendica (Network Enhancements for the Next Decade) Industry Connections Project
- **Action B3 led 802.11 to create the 802.11 AANI SC [2]:**

Advanced Access Network Interface Standing Committee

802.11 AANI SC Liaison Statements

- **The AANI SC has sent, replied to, and received liaison statements with 3GPP:**

Liaison Statements Sent:

- **LS (11-16/1101r10) to 3GPP RAN & SA (9/16)**
- **LS (11-16/1510r2) to 3GPP RAN2 (1/17)**
- **LS (11-16/1573r3) to 3GPP RAN (1/17)**
- **LS (11-17-0378r2) to 3GPP RAN2 (5/17)**
- **LS (11-16/1574r3) to 3GPP SA (5/17)**
- **LS (11-17/1744r3) to NGMN (11/17)**
- **LS (11-17/1750r3) to IEEE 5G (11/17)**
- **LS (11-18/1340r6) to 3GPP/WFA/WBA (11/18)**
- **LS (11-19/1300r1) to 3GPP SA (7/19)**

Liaison Statements Received:

- **3GPP RAN2 WG LS (11-17/0315r0) (3/17)**
- **3GPP RAN TSG LS (11-17/0444r0) (3/17)**
- **3GPP SA TSG LS (11-17/0903r0) (6/17)**
- **NGMN LS (11-17/1569r0) (10/17)**