IEEE P802.11
Wireless LANs

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| Comments on 11-20-0013-03-aani-draft-technical-report-on-interworking-between-3gpp-5g-network-wlan |
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Abstract

This contribution provides a number of comments on “AANI-11-20-0013-03-aani-draft-technical-report-on-interworking-between-3gpp-5g-network-wlan”

Revision History

Rev.0 uploaded initial comments

Rev.1 Fixed the format and style by updating the authors and abstract sections.

Rev.2 Fixed the title of the contribution

Original Rev.0-2 were improperly formatted and titled. This is an R3 renamed to R0 and the old versions were removed.

1. **Definition, acronyms and abbreviations**
	1. **Definitions**

**ANC**  Access network control function of WLAN access network, which refers to IEEE 802 network reference model [18].

**NWu** Reference point between the UE and N3IWF for establishing secure tunnel(s) between the UE and N3IWF so that control-plane and user-plane exchanged between the UE and the 5G Core Network is transferred securely over untrusted non-3GPP access, which refers to 3GPP TS 23.502 [9]. This is in the domain of WLAN access network.

**STA** WLAN STA consists of TEC (terminal control) and TEI (terminal data path interface), which refers to IEEE 802 network reference model [18].

**N1** Reference point between the UE and the AMF in 5G core network [8].

**N2**  Reference point between the (R)AN and the AMF in 5G core network [8].

**N3** Reference point between the (R)AN and the UPF in 5G core network [8].

**N4** Reference point between the SMF and the UPF in 5G core network [8]

**N7** Reference point between the SMF and the PCF in 5G core network [8].

**N11** Reference point between the AMF and the SMF in 5G core network [8].

**N15** Reference point between the PCF and the AMF in the case of non-roaming scenario, PCF in the visited network and AMF in the case of roaming scenario in 5G core network [8].

**Y1**  Reference point for PHY/MAC layer function between STA and the untrusted non-3GPP access network (e.g. WLAN). This depends on the non-3GPP access technology. This is in the domain of WLAN access network.

**Y2**  Reference point for PHY/MAC layer function between the untrusted non-3GPP access network (e.g. WLAN) and the N3IWF for the transport of NWu traffic which refers 3GPP TS 23.502. This is in the domain of WLAN access network.

**Y3**  Reference point for control and management interface between STA and the untrusted non-3GPP access network (e.g. WLAN). This depends on the non-3GPP access technology. This is in the domain of WLAN access network.

**Y4**  Reference point for control and management interface between the untrusted non-3GPP access network (e.g. WLAN) and the N3IWF for the transport of NWu traffic which refers 3GPP TS 23.502. This is in the domain of WLAN access network.

* 1. **Acronyms and abbreviations**

**3GPP** 3rd Generation Partnership Project

**5G** 5th Generation

**5G-AN** 5th Generation Access Network

**AIFS** Arbitrary Inter-Frame Spacing

**AN** Access Network

**ANC**  Access Network Control

**AMF**  Access and Mobility Management Function

**ATSSS** Access Traffic Steering Switching and Splitting

**CN** Core Network

**HCCA** Hybrid Controlled Channel Access

**EAP-5G** Extended Authentication Protocol-5th Generation

**EDCA** Enhanced Distributed Channel Access

**GBR** Guaranteed Bit Rate

**GRE** Generic Routing Encapsulation

**IKEv2** Initial Key Exchange Protocol Version 2

**IP** Internet Protocol

**IPsec** Internet Protocol Security

**MAC** Media Access Control

**NAS** Non-Access Stratum

**N3IWF** Non-3GPP Inter Working Function

**PCF** Policy Control Function

**PDU** Packet Data Unit

**PER** Packet Error Rate

**PHY**  Physical Layer

**RAN** Radio Access Network

**RAT** Radio Access Technology

**QoS** Quality of Service

**SMF** Session Management Function

**STA** Station

**TEC** Terminal Control

**TEI** Terminal Interface

**TSN** Time Sensitive Network

**UE**  User Equipment

**UPF**  User Plane Function

**V2X** Vehicle to Anything

**WLAN** Wireless Local Area Network

1. **Introduction**

This clause introduces objective and scope of the technical report on WLAN interworking to 3GPP 5G core network. WLAN interworking types can be divided into tightly coupled or loosely coupled model, and functional reference model to interwork with 3GPP 5G network is described in Clause 3.

Clause 4 describes the interworking function and specific procedures regarding radio channel sharing, registration and authentication, IP tunneling, ATSSS and QoS function, and Clause 5 describes technical gap analysis and technical recommendations. Finally, conclusions are summarized in Clause 6.

* 1. **Objective**

This technical report on interworking between 3GPP 5G network and WLAN provides a reference and guideline for stakeholders with interest in standardization and system development of WLAN (IEEE Std. 802.11).

* 1. **Scope**

This report covers an interworking reference model, necessary functionalities and specific procedures that allow WLAN access networks to interwork with 3GPP 5G network. Two types of interworking reference models are considered: a tightly coupled model and loosely coupled model.

The interworking reference model consists of terminal part (an UE and a STA), access networks (3GPP and WLAN), 3GPP 5G core network and sever as shown in Figure 1. Two access networks are connected to server via 3GPP 5G core network. 3GPP access network and 5G core network are defined in 3GPP specification and WLAN access network considered is defined in the IEEE 802 network reference model of IEEE 802.1CF-2019 [18].



Figure 1. Overview of WLAN interworking with 3GPP 5G core network

1. **WLAN interworking reference model**
	1. **WLAN interworking types**

The tightly coupled interworking type assumes that functional entities of terminal and the two access networks are combined together and connect to 3GPP core network. Allowing a co-located 3GPP Access Network and WLAN Access Network to operate in a coordinated manner provides wireless services via the 3GPP 5G Core Network. This interworking model allows for the optimization of overall system performance by integrating the access of the two access networks from architecture design perspective, enabling improved overall network access to services.

The loosely coupled interworking type assumes that 3GPP and WLAN access networks are not co-located and two access networks operate independently. The terminal (UE and STA) functions can be combined or separated. This type of interworking can provide the same service functions as a tightly coupled interworking type, though the optimization of access to the two access networks will not be coordinated.

Both, the tightly and loosely coupled interworking types assume that the terminal device has a co-located UE (3GPP Access) and STA (WLAN Access).



Figure 2. Tightly coupled interworking reference model between 5G core network and WLAN



Figure 3. Loosely coupled interworking reference model between 5G core network and WLAN

Interworking with WLAN has been an essential feature in the 3GPP LTE-based (4G) cellular systems. 3GPP has specified [2-4] both RAN level interworking and CN level interworking mechanisms. When defining radio assess to the 5G Core Network, 3GPP has allowed WLAN access as a non-3GPP RAT (Radio Access Technologies) that can be connected to 5G Core Network (CN) via the N3IWF (Non-3GPP Interworking Function) or the TNGF (Trusted Non-3GPP Gateway Function) depending on whether the WLAN is trusted or non-trusted [8].

For trusted non-3GPP access, the user plane protocol stack is as follows:



Figure 4. Use plane protocol stacks for trusted non-3GPP access (3GPP TS 23.501)

For untrusted non-3GPP access, the user plane protocol stack is as follows:



Figure 5. Use plane protocol stacks for untrusted non-3GPP access (3GPP TS 23.501)

* 1. **WLAN interworking functional model**

WLAN interworking function model consists of UE/STA terminal, 3GPP/WLAN access network and 3GPP core network as shown in Figure 6.

WLAN STA functions are divided into terminal interface (TEI) and terminal control (TEC). And WLAN access network functions are divided into WLAN access data path and access network control (ANC) according to the WLAN network reference model of IEEE 802.1CF-2019 [18]. 3GPP functions are divided into UE and 3GPP access network, 5G core network and their signaling interfaces are described according to 3GPP specification [8-9].

For WLAN interworking to 3GPP core network, 3GPP NWu interface signaling shall be processed in WLAN domainand N1 signaling is transparently forwarded in WLAN domain. The N1 interface provides the signaling procedures between UE and 3GPP core network supporting Authentication and Mobility Function (AMF). The NWu interface provides the signaling procedures between UE and N3IWF of 3GPP core network to support a secured IP channel.

In WLAN domain, Y1 and Y2 interfaces support the data flow via the PHY and MAC layers of STA and WLAN access network. And Y3 and Y4 interfaces are control and management interface to providing ATSSS and QoS management. These red colored Y1, Y2, Y3 and Y4 interfaces are in the domain of WLAN and may be provided in STA and WLAN access network. The other reference interfaces are defined in the 3GPP core network specifications [10-12].



Figure 6. WLAN interworking reference model with 5G core network

1. **Interworking function and procedures**

The radio channel access and communication procedures have to be specified to enable WLAN interworking with 5G core network. Even though there are tightly coupled or loosely coupled interworking types, common procedures can support both types.

A radio channel sharing method is described in 4.1. Initial registration and authentication procedures between STA of UE and AMF of 5G core network are described in 4.2. Example IP secure transport and data exchange procedures between the STA of the terminal device and UPF of 5G core network are described in 4.3.

ATSSS function and QoS management procedures to support WLAN are expected to require interface additions or modification to the MAC layer of STA and wireless access network. These functions are described in 4.4 and 4.5.

* 1. **WLAN radio channel sharing method**

For ATSSS support, TEI of STA monitors the usage of WLAN access network (monitoring if the radio channel is busy or idle). If the radio channel is idle, the STA may attempt to send control or traffic data through the WLAN radio channel. If the radio channel is busy, the STA will not send control of traffic data through the WLAN radio channel, it will wait until the radio channel is idle.

* 1. **Registration and authentication and its message procedures**

STA shall initially support registration and authentication to establish a connection between Terminal and N3IWF. NWu for registration and authorization involves IP protocol, IKEv2 and EAP-5G protocol, and secured signaling tunnel over N1 (a.k.a. signaling radio bearer) is required to exchange NAS signals.

* + 1. **Registration and authentication function**

TEC of STA in the Terminal and ANC of WLAN access network shall have specific functional requirements to interwork with 3GPP 5G core network

* IP communication protocol
* IKEv2 authorization protocol
* EAP-5G protocol
* NAS signaling



Figure 7. Control plane between STAand N3IWF (3GPP TS 23.501)

* + 1. **Message procedures**
* **Y2 interface**

Y2 interface is PHY/MAC data communication protocol between ANC of WLAN access network and N3IWF of 3GPP 5G core network. Y2 follows IEEE 802.3 standard.



Figure 8. Y2 interface

* **NWu interface**

NWu interface is IP based communication protocol between STA of WLAN access network and N3IWF of 3GPP 5G core network to establish secured data channel. IKEv2 authorization protocol and EAP-5G protocol is applied



Figure 9. NWu interface

* **N1 interface**

N1 interface is secured IP communication protocol between UE of WLAN access network and AMF of 3GPP 5G core network to provide NAS signaling



Figure 10. N1 interface

* 1. **IP Tunneling function and its message procedures**

STA shall initially support secured IP transport between terminal unit and UPF, and traffic data is exchanged over the established IP channel.

* + 1. **IP Tunneling Function**

SC of UE and ANC of WLAN access network shall have specific functional requirements to interwork with 3GPP 5G core network.

* IP communication protocol
* IPsec communication protocol
* GRE communication protocol



Figure 11. Data plane between STA and N3IWF (3GPP TS 23.501)

* + 1. **Message procedures**

* IPsec tunneling procedures shall be processed via WLAN access network
* PDU session establishment shall be processed via WLAN access network.
	1. **ATSSS function support**

Traffic data shall be transmitted over WLAN access channel and/or 3GPP access channel by using ATSSS function.

* 3GPP supports ATSSS between 3GPP and non-3GPP access networks
* ATSSS can enable traffic selection, switching and splitting between 5G-AN and WLAN



Figure 12. Architecture reference model for ATSSS support (3GPP TS 23.501)

The 3GPP QoS flow is access agnostic, so the same QoS should be supported when the traffic is distributed over 5G access network and WLAN access network as long as the WLAN access network can provide the same QoS treatment as 5G access network. The QoS flow may be either guaranteed flow bit rate (GBR) or Non-GBR, so 3GPP can support GBR traffic as well as Non-GBR traffic defined in 3GPP TS 23.501 as follows:

* GBR QoS Flow: A QoS Flow using the GBR resource type or the Delay-critical GBR resource type and requiring guaranteed flow bit rate.
* Non-GBR QoS Flow: A QoS Flow using the Non-GBR resource type and not requiring guaranteed flow bit rate.

Table 1 shows the characteristics of GBR and delay critical GBR QoS flows from 3GPP. Therefore, it is required to consider how to support GBR flows in WLAN. The key point is how to provide GBR support in two directions, e.g. STA to AP and AP to STA. The following table is applicable to two directions.

Table 1. QoS characteristics (3GPP TS 23.501)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Resource Type | Default Priority Level | Packet Delay Budget | Packet ErrorRate  | Default Maximum Data Burst Volume | DefaultAveraging 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 messagesElectricity 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]) |

* 1. **QoS function and its message procedures**

3GPP resource types and QoS related parameters shall be shared with WLAN using Y3 and Y4 interfaces and WLAN will support QoS function and related message procedures. QoS management functions need to cover QoS mapping, scheduling algorithm and MAC interface and TEC of STA and ANC of WLAN access network will deal with them.

PHY and MAC specification are important factor to meet the required QoS value. The current technologies to provide QoS management is EDCA and HCCA, which are distributed based access scheme. IEEE 802.11e provides 4 kinds of access categories, which are best effort, video probe, video and voice. According to access categories, contention widow size and arbitration inter-frame space (AIFS) is variable to meet the required quality of service.

3GPP specification provides GBR, Non-GBR and delay critical GBR. Delay critical GBR needs lower latency (less than 30msec) and higher packet error rate (PER) (less than 10-4). And 3GPP have more characterized QoS management to support packet delay, PER, default maximum data burst volume and default average window for the service types.

It is reviewed that EDCA and HCCA of WLAN technology will meet QoS for Non-GBR service type and will be limited to meet low latency and high reliability for GBR and delay critical GBR types.

1. **Gap analysis and Recommendations**
	1. **Gap Analysis**

WLAN interworking to 3GPP core network can have merits in terms of access and mobility, QoS managed ATSSS of packet data service. However, new functional entities and signaling procedures are required for WLAN to support these capabilities. In this section, we identify and analyze gaps in the current WLAN specification which must be addressed to allow full interwork with 3GPP core network.

New functional entities to support interwork with 3GPP core network that are not currently in the WLAN specification are: a radio sharing function, registration and authentication, NAS message transport, IP tunneling, Packet session control, and QoS managed ATSSS.

A radio sharing function with Y1 interfaces can be implemented by WLAN channel scanning and association procedure. Registration and authentication should have IP communication protocol, IKEv2 and EAP-5G communication protocol using Y3 and Y4 interfaces. NAS messages with Y3 and Y4 interfaces should have IPsec and GRE communication protocol referred from 3GPP specification.

 IP tunneling and packet session control with Y3 and Y4 interfaces should refer to IPsec and GRE protocol specified by 3GPP core network. ATSSS function with Y1 and Y2 interfaces is packet data transmission specified by WLAN 802.11 specification. QoS management with Y3 and Y4 interfaces should define QoS identification and profiling.

Table 2. New functional entities and communication protocols to interwork with 3GPP core network

|  |  |  |
| --- | --- | --- |
| New functional entities | Communication protocols | WLAN interfaces |
| Radio sharing function  | Channel scanning and association  | Y1 |
| Registration & authentication  | IP protocol, IKEv2 and EAP-5G protocol | Y3 and Y4 |
| IP tunneling  | IPsec and GRE protocol  | Y3 and Y4 |
| Packet session control  | Session control protocol | Y3 and Y4 |
| ATSSS | Packet data transmission  | Y1 and Y2 |
| QoS management | QoS identification and profile | Y3 and Y4  |

In the view of higher layer control and protocol to interwork with 3GPP 5G core network, IKEv2, EAP-5G, IPsec and GRE protocol are referred to IETF specification and modified for interworking. And these protocols can be implemented in TEC of the STA and ANC of WLAN access network.

NAS signaling to AMF and packet session control to SMF are referred to 3GPP specification and can be implemented in TEC and ANC of WAN access network. And WLAN QoS management is referred to IEEE 802.11e and should be adapted to support fine granularity of QoS levels.

Table 3. New signaling to interwork with 3GPP core network

|  |  |  |
| --- | --- | --- |
| Communication protocols | Related WLAN function  | Related WLAN Specification |
| IKEv2 | TEC, ANC | IETF Internet Key Exchange Protocol |
| EAP-5G | TEC, ANC | IETF EAP protocol |
| IPsec | TEC, ANC  | IETF IPsec protocol  |
| NAS | TEC, ANC | 3GPP Protocol |
| GRE  | TEC, ANC | IETF ESP protocol |
| Session control | TEC, ANC | 3GPP protocol |
| QoS identification and profile | TEC, ANC | IEEE 802.11e |

In QoS management, the current IEEE 802.11-2016 covers four classes: background, best effort, audio and video. And QoS is managed according to service class, contention window and AIFS value. Thus, WLAN currently can support only non-GBR service and has to consider QoS identification and profile to support GBR service. 3GPP system specifies QoS profile and characteristics in QoS level as follows;

* Service priority level
* Packet latency
* Packet error rate
* Guaranteed data rate
* Averaging window

TEC of STA and ANC of WAN access network should process QoS management according to QoS profile provided by 3GPP 5G core network.

Table 4. Service categories to interwork with 3GPP core network

|  |  |  |
| --- | --- | --- |
| Service Categories | Related WLAN function | Related WLAN Specification |
| Non-GBR | 4 service classes; Background, Best effort, audio and video  | IEEE 802.11e |
| GBR | To be defined in fine granularity of service classes and QoS management | Shall specify QoS mapping and scheduling. And IEEE 802.1 TSN is for deterministic Ethernet network. |

The SMF assigns QoS profile and QoS rule to AN in WLAN domain with QoS Flow Identification (QFI) of the packet data. QoS profile and QoS rule define the QoS parameters for the packet data unit. And QoS flow is mapped to AN resources for the assigned QFI.



Figure 13. QoS flows and mapping to AN resources in user plane (3GPP TS 23.501)

Table 5. Gap analysis of GBR service between 3GPP 5G network and WLAN

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 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 EDCA is CSMA based MAC and supports only 4 service types of best effort, back ground, voice and video by controlling TXOP, AIFSN & contention window size. . 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  | 10-8 | N/A |
| "Live" Uplink Streaming  | 500 ms  | 10-8 | N/A |
| "Live" Uplink Streaming  | 500 ms | 10-4 | N/A |
| 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 |

3GPP QoS flow in SMF defines QoS identification and its priority according to resource types and QoS information is transferred to AP and STA.

At first, QoS mapping from 3GPP QoS to WLAN QoS is necessary. WLAN shall support fine granularity of QoS and priority because 5G QoS ID has 6bits and specifies QoS parameters involving GBR (Guaranteed Bit Rate), latency and PER. Secondly, 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. Packet scheduler configures data rate, packet latency, PER and packet size for MSDU packet.

It is reported that transmission time scheduling guaranteed low packet latency and Hybrid ARQ supports PER improvement. And data rate and bandwidth control shall support GBR.



Figure 14. QoS mapping and scheduling example of WLAN

3GPP 5G System can be integrated with the external TSN as a TSN bridge. The TSN bridge includes TSN Translator functionality for interoperation between TSN System and 5G System both for user plane and control plane. 5G system TSN translator functionality consists of Device-side TSN translator (DS-TT) and Network-side TSN translator (NW-TT). 5G system specific procedures in a 5G core network and RAN, wireless communication links, etc. remain hidden from the TSN network [8]

As for TSN applications such as smart factory and automation field, TSN bridges can be configured in three different types. The first type is to use 5G system as a TSN bridge in Figure 15. 3GPP domain needs to consider the timing synchronization and TSN translator (TT) function in UE and 5G CN. The second type is to use WLAN and 5G CN interworking as a TSN bridge in Figure 16. The third type is to use WLAN only as a TSN bridge in Figure 17.



Figure 15. TSN Bridge using 5G AN and CN



Figure 16. TSN Bridge using WLAN and 5G CN interworking



Figure 17. TSN Bridge using WLAN only

* 1. **Technical Recommendations**

WLAN supports high data rate to meet the performance of 5G network vision in the low mobility scenario and it is integrated as one of access networks for 3GPP 5G network. Therefore, 802.11 should consider adding new functional entities and signaling procedures to support interworking with the 3GPP 5G network. The following new functional entities should be added:

* Radio scanning and association
* Registration and authentication
* NAS signaling messages
* Packet session initiation/modification/termination
* Packet data QoS management

The key considerations on WLAN to interwork 5G core network as follows;

* Radio scanning and association process is well specified in WLAN 802.11 and is capable of supporting WLAN interworking with the 5G core network.
* IKEv2, EAP-5G and IPsec protocol for registration and authentication support should be added in the TEC of the STA and ANC of WLAN access network.
* NAS signaling to connect AMF should be added in the TEC of the STA and ANC of the WLAN access network.
* Packet session initiation/modification/termination to connect SMF should be added in TEC of the STA and ANC of WLAN access network.
* Packet data QoS management of WLAN shall specify QoS identification, profile and DRB to guarantee packet delay and PER for the required service types.
	+ 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 introduction of a Hybrid ARQ scheme are very important
	+ 802.11ax cannot support 3GPP service QoS, and improved version (11be EHT, 11bd NGV) should consider MAC enhancement to support the service requirements.

For TSN applications, WLAN domain needs to consider the following requirements

* + Timing synchronization
	+ TSN translation in WLAN STA and 5G CN
1. **Conclusions**

WLAN can support interworking with the 3GPP 5G network and is able to support high data rate to meet the performance of 5G network vision in the low mobility scenario. The new functional entities and signaling procedures were identified:

* Radio scanning and association
* Registration and authentication
* NAS signaling messages
* Packet session initiation/modification/termination
* Packet data QoS management

Through gap analysis, IEEE WLAN radio scanning and association process, IETF specification such as IKEv2, EAP-5Ga and IPsec can be used or adaptedand implemented in TEC of the STA and ANC of WLAN access network. NAS signaling, ATSSS and QoS management can be implemented in TEC of the STA and ANC of WLAN access network, and should follow the guidance of the 3GPP specifications.

As for QoS management, WLAN should specify QoS mapping and MAC scheduling including QoS identification and profile to guarantee QoS in terms of deterministic packet delay, low PER and data rate.

For TSN applications, WLAN domain needs to consider the timing synchronization with TSN domain and TSN translation in WLAN STA and 5G CN.

1. **References**
2. 3GPP TS 22.261 V15.5.0 (2018-06) “Service requirements for the 5G system (Stage 1)”
3. 3GPP TS 22.278 “Service requirements for the Evolved Packet System (EPS)”
4. 3GPP TS 23.401 “EPS Architecture and Procedures”
5. 3GPP TS 23.402 "Architecture enhancements for non-3GPP accesses”
6. 3GPP TR 23.716 “Study on the Wireless and Wireline Convergence for the 5G System Architecture”
7. 3GPP TR 23.793 “Study on Access Traffic Steering, Switching and Splitting support in the 5G system architecture”
8. 3GPP TR 23.799“Study on Architecture for Next Generation System”
9. 3GPP TS 23.501“System Architecture for the 5G System (Stage 2)”
10. 3GPP TS 23.502“Procedures for the 5G System (Stage 2)”
11. 3GPP TS 24.302 “Access to the 3GPP Evolved Packet Core (EPC) via non-3GPP access networks (Stage 3)”
12. 3GPP TS 24.501 “Non-Access-Stratum (NAS) protocol for 5G System (5GS) (Stage 3)”
13. 3GPP TS 24.502 “Access to the 3GPP 5G Core Network (5GCN) via Non-3GPP Access Networks (N3AN) (Stage 3)”
14. 3GPP TS 33.501 “Security Architecture and Procedure for the 5G System”
15. 3GPP TR 33.899 “Study on the Security Aspects of the Next Generation System”
16. 3GPP TS 37.324 “Service Data Adaptation Protocol (SDAP) Specification”
17. 3GPP TS 38.300 “NR and NG-RAN Overall Description”
18. RAN convergence paper, WBA and NGMN alliance, September 2019.
19. IEEE 802.1CF-2019; IEEE Recommended Practice for Network Reference Model and Functional Description of IEEE 802® Access Network, 2019.