5G Advanced and B5G (Beyond 5G) Networks

5G Personal IoT Networks (PINs)

with selected "5G Advanced" System selected Feature Capabilities

to

LF Edge Akraino TSC

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Mobile Networks to evolve from:

a Design that offers "Best-effort Services

to

a Design that offers Performance and User Experience Guarantees

Capabilities related to e.g.:

When a *Multi-access* (**MA**) **PDU Session** is established, the Network may provide the UE with *Measurement Assistance Information* to enable the UE in determining which measurements shall be performed over both Accesses, as well as whether measurement reports need to be sent to the Network.

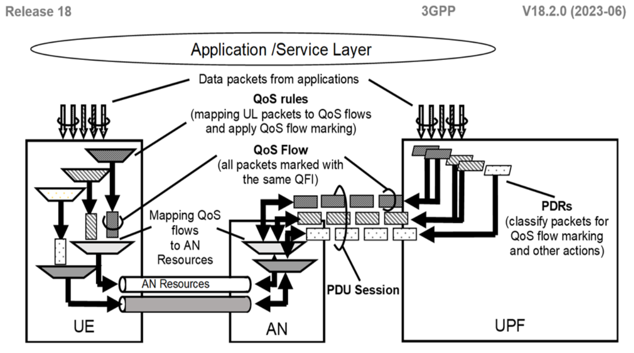

Figure: The 5G Principle for Classification and User Plane (UP) marking for QoS Flows and mapping to AN Resources

Measurement Assistance Information shall include the addressing information of a Performance Measurement Function (**PMF**) in the UPF, the UE can send PMF protocol messages incl.:

- Messages to allow for *Round Trip Time* (**RTT**) Measurements: the "*Smallest Delay*" steering mode is used or when either "*Priority-based*", "*Load-Balancing*" or "**Redundant**" steering mode is used with RTT threshold value being applied;
- Messages to allow for *Packet Loss Rate* (**PLR**) measurements, i.e. when steering mode is used either "*Priority-based*", "*Load-Balancing*" or "*Redundant*" steering mode is used with **PLR** threshold value being applied;
- Messages for reporting Access Availability/Un-availability by the UE to the UPF.
- Messages for sending **UE-assistance Data** to **UPF.**
- Messages for sending "*Suspend Traffic Duplication*" and "*Resume Traffic Duplication*" from **UPF** to **UE** to "suspend" or "resume" traffic duplication as defined in **5GS Architecture**.

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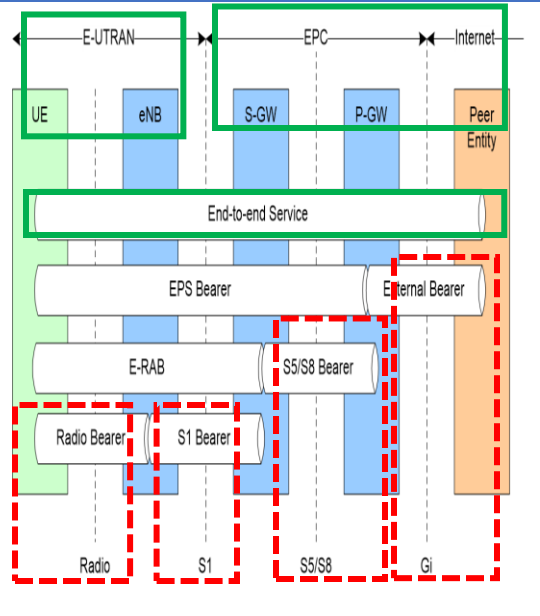

Figure : EPS Bearer Service Architecture

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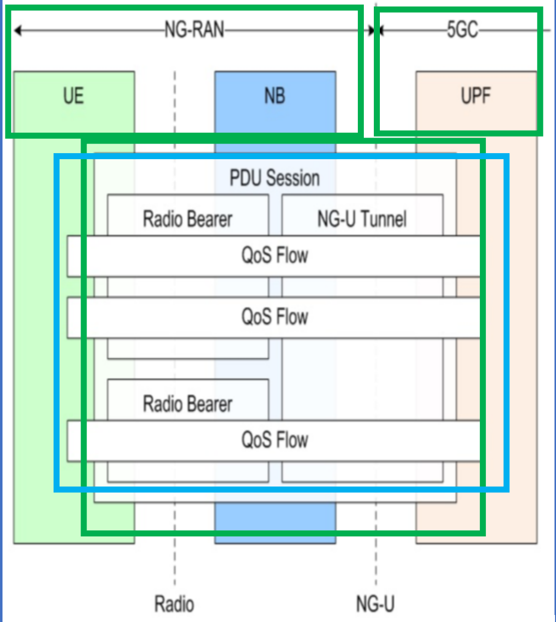


Figure: 5G CN NG-RAN Bearer Services QoS Architecture

5G SA/SBA (5GC and NG-RAN) QoS 5QI (5G QoS Identifier)

5QI Value	Resource Type	Default Priority Level	Packet Delay Budget (NOTE 3)	Packet Error Rate	Default Maximum Data Burst Volume (NOTE 2)	Default Averaging Window	Example Services
1	GBR (NOTE 1)	20	100 ms (NOTE 11, NOTE 13)	10^{-2}	N/A	2000 ms	Conversational Voice
2		40	150 ms (NOTE 11, NOTE 13)	10^{-3}	N/A	2000 ms	Conversational Video (Live Streaming)
3		30	50 ms (NOTE 11, NOTE 13)	10^{-3}	N/A	2000 ms	Real Time Gaming, V2X messages (see Electricity distribution – medium voltage, Process automation monitoring
4		50	300 ms (NOTE 11, NOTE 13)	10^{-6}	N/A	2000 ms	Non-Conversational Video (Buffered Streaming)
65 (NOTE 9, NOTE 12)		7	75 ms (NOTE 7, NOTE 8)	10^{-2}	N/A	2000 ms	Mission Critical user plane Push To Talk voice (e.g. MCPTT)
66 (NOTE 12)		20	100 ms (NOTE 10, NOTE 13)	10^{-2}	N/A	2000 ms	Non-Mission-Critical user plane Push To Talk voice
67 (NOTE 12)		15	100 ms (NOTE 10, NOTE 13)	10^{-3}	N/A	2000 ms	Mission Critical Video user plane
75 (NOTE 14)							
71		56	150 ms (NOTE 11, NOTE 13, NOTE 15)	10^{-6}	N/A	2000 ms	"Live" Uplink Streaming (e.g.
72		56	300 ms (NOTE 11, NOTE 13, NOTE 15)	10^{-4}	N/A	2000 ms	"Live" Uplink Streaming (e.g.
73		56	300 ms (NOTE 11, NOTE 13, NOTE 15)	10^{-8}	N/A	2000 ms	"Live" Uplink Streaming (e.g.
74		56	500 ms (NOTE 11, NOTE 15)	10^{-8}	N/A	2000 ms	"Live" Uplink Streaming (e.g.
76		56	500 ms (NOTE 11, NOTE 13, NOTE 15)	10^{-4}	N/A	2000 ms	"Live" Uplink Streaming (e.g.
5	Non-GBR (NOTE 1)	10	100 ms NOTE 10, NOTE 13)	10^{-6}	N/A	N/A	IMS Signalling
6		60	300 ms (NOTE 10, NOTE 13)	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 (NOTE 10, NOTE 13)	10^{-3}	N/A	N/A	Voice, Video (Live Streaming) Interactive Gaming
8		80	300 ms (NOTE 13)	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					
10		90	1100ms (NOTE 13) (NOTE 17)	10^{-6}	N/A	N/A	Video (Buffered Streaming) TCP-based (e.g. www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.) and any service that can be used over satellite access type with these characteristics
69 (NOTE 9, NOTE 12)		5	60 ms (NOTE 7, NOTE 8)	10^{-6}	N/A	N/A	Mission Critical delay sensitive signalling (e.g. MC-PTT signalling)
70 (NOTE 12)		55	200 ms (NOTE 7, NOTE 10)	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 (NOTE 10, NOTE 13)	10^{-2}	N/A	N/A	V2X messages (see
80		68	10 ms (NOTE 5, NOTE 10)	10^{-6}	N/A	N/A	Low Latency eMBB applications Augmented Reality
82	Delay-critical GBR	19	10 ms (NOTE 4)	10^{-4}	255 bytes	2000 ms	Discrete Automation
83		22	10 ms (NOTE 4)	10^{-4}	1354 bytes (NOTE 3)	2000 ms	Discrete Automation V2X messages (UE - RSU Platooning, Advanced Driving: Cooperative Lane Change with low LoA,
84		24	30 ms (NOTE 6)	10^{-5}	1354 bytes (NOTE 3)	2000 ms	Intelligent transport systems (see
85		21	5 ms (NOTE 5)	10^{-5}	255 bytes	2000 ms	Electricity Distribution- high voltage (see V2X messages (Remote Driving. See NOTE 16, see
86		18	5 ms (NOTE 5)	10^{-4}	1354 bytes	2000 ms	V2X messages (Advanced Driving: Collision Avoidance, Platooning with high LoA. See
87		25	5 ms (NOTE 4)	10^{-3}	500 bytes	2000 ms	Interactive Service - Motion tracking data,
88		25	10 ms (NOTE 4)	10^{-3}	1125 bytes	2000 ms	Interactive Service - Motion tracking data,
89		25	15 ms (NOTE 4)	10^{-4}	17000 bytes	2000 ms	Visual content for cloud/edge/split rendering (see
90		25	20 ms (NOTE 4)	10^{-4}	63000 bytes	2000 ms	Visual content for cloud/edge/split rendering (see

NOTE 1: A packet which is delayed more than PDB is not counted as lost, thus not included in the PER.
NOTE 2: It is required that default MDBV is supported by a PLMN supporting the related 5QIs.
NOTE 3: The Maximum Transfer Unit (MTU) size considerations in clause 9.3 and Annex C of TS 23.060 [56] are also applicable. IP fragmentation may have impacts to CN PDB, and details are provided in clause 5.6.10.
NOTE 4: A static value for the CN PDB of 1 ms for the delay between a UPF terminating N6 and a 5G-AN should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface. When a dynamic CN PDB is used, see clause 5.7.3.4.
NOTE 5: A static value for the CN PDB of 2 ms for the delay between a UPF terminating N6 and a 5G-AN should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface. When a dynamic CN PDB is used, see clause 5.7.3.4.
NOTE 6: A static value for the CN PDB of 5 ms for the delay between a UPF terminating N6 and a 5G-AN should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface. When a dynamic CN PDB is used, see clause 5.7.3.4.
NOTE 7: For Mission Critical services, it may be assumed that the UPF terminating N6 is located "close" to the 5G_AN (roughly 10 ms) and is not normally used in a long distance, home routed roaming situation. Hence a static value for the CN PDB of 10 ms for the delay between a UPF terminating N6 and a 5G_AN should be subtracted from this PDB to derive the packet delay budget that applies to the radio interface.
NOTE 8: In both RRC Idle and RRC Connected mode, the PDB requirement for these 5QIs can be relaxed (but not to a value greater than 320 ms) for the first packet(s) in a downlink data or signalling burst in order to permit reasonable battery saving (DRX) techniques.
NOTE 9: It is expected that 5QI-65 and 5QI-69 are used together to provide Mission Critical Push to Talk service (e.g. 5QI-5 is not used for signalling). It is expected that the amount of traffic per UE will be similar or less compared to the IMS signalling.
NOTE 10: In both RRC Idle and RRC Connected mode, the PDB requirement for these 5QIs can be relaxed for the first packet(s) in a downlink data or signalling burst in order to permit battery saving (DRX) techniques.
NOTE 11: In RRC Idle mode, the PDB requirement for these 5QIs can be relaxed for the first packet(s) in a downlink data or signalling burst in order to permit battery saving (DRX) techniques.
NOTE 12: This 5QI value can only be assigned upon request from the network side. The UE and any application running on the UE is not allowed to request this 5QI value.
NOTE 13: A static value for the CN PDB of 20 ms for the delay between a UPF terminating N6 and a 5G-AN should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface.
NOTE 14: This 5QI is not supported in this Release of the specification as it is only used for transmission of V2X messages over MBMS bearers as defined in TS 23.285 [72] but the value is reserved for future use.
NOTE 15: For "live" uplink streaming (see TS 26.238 [76]), guidelines for PDB values of the different 5QIs correspond to the latency configurations defined in TR 26.939 [77]. In order to support higher latency reliable streaming services (above 500ms PDB), if different PDB and PER combinations are needed these configurations will have to use non-standardised 5QIs.
NOTE 16: These services are expected to need much larger MDBV values to be signalled to the RAN. Support for such larger MDBV values with low latency and high reliability is likely to require a suitable RAN configuration, for which, the simulation scenarios in TR 38.824 [112] may contain some guidance.
NOTE 17: The worst case one way propagation delay for GEO satellite is expected to be ~270ms, ,~ 21 ms for LEO at 1200km, and 13 ms for LEO at 600km. The UL scheduling delay that needs to be added is also typically 1 RTD e.g. ~540ms for GEO, ~42ms for LEO at 1200km, and ~26 ms for LEO at 600km. Based on that, the 5G-AN Packet delay budget is not applicable for 5QIs that require 5G-AN PDB lower than the sum of these values when the specific types of satellite access are used (5QI-10 can accommodate the worst case PDB for GEO satellite type.

NOTE: It is preferred that a value less than 64 is allocated for any new standardised 5QI of Non-GBR resource type. This is to allow for option 1 to be used as described in clause 5.7.1.3 (as the QFI is limited to less than 64).

4G/LTE (EPC & E-UTRAN) QoS QCI (QoS Class Identifier)

QCI	Resource Type	Priority Level	Packet Delay Budget (NOTE 13)	Packet Error Loss Rate (NOTE 2)	Example Services
1 (NOTE 3)	GBR	2	100 ms (NOTE 1, NOTE 11)	10^{-2}	Conversational Voice
2 (NOTE 3)	GBR	4	150 ms (NOTE 1, NOTE 11)	10^{-3}	Conversational Video (Live Streaming)
3 (NOTE 3, NOTE 14)	GBR	3	50 ms (NOTE 1, NOTE 11)	10^{-3}	Real Time Gaming, V2X messages Electricity distribution - medium voltage (e.g. clause 7.2.2 Process automation - monitoring (e.g.
4 (NOTE 3)	GBR	5	300 ms (NOTE 1, NOTE 11)	10^{-6}	Non-Conversational Video (Buffered Streaming)
65 (NOTE 3, NOTE 9, NOTE 12)	GBR	0.7	75 ms (NOTE 7, NOTE 8)	10^{-2}	Mission Critical user plane Push To Talk voice (e.g., MCPTT)
66 (NOTE 3, NOTE 12)	GBR	2	100 ms (NOTE 1, NOTE 10)	10^{-2}	Non-Mission-Critical user plane Push To Talk voice
67 (NOTE 3, NOTE 12)	GBR	1.5	100 ms (NOTE 1, NOTE 10)	10^{-3}	Mission Critical Video user plane
75 (NOTE 14)	GBR	2.5	50 ms (NOTE 1)	10^{-2}	V2X messages
71	GBR	5.6	150ms (NOTE 1, NOTE 16)	10^{-6}	"Live" Uplink Streaming
72	GBR	5.6	300ms (NOTE 1, NOTE 16)	10^{-4}	"Live" Uplink Streaming
73	GBR	5.6	300ms (NOTE 1, NOTE 16)	10^{-8}	"Live" Uplink Streaming
74	GBR	5.6	500ms (NOTE 1, NOTE 16)	10^{-8}	"Live" Uplink Streaming
76	GBR	5.6	500ms (NOTE 1, NOTE 16)	10^{-4}	"Live" Uplink Streaming
5 (NOTE 3)	Non-GBR	1	100 ms (NOTE 1, NOTE 10)	10^{-6}	IMS Signalling
6 (NOTE 4)	Non-GBR	6	300 ms (NOTE 1, NOTE 10)	10^{-6}	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7 (NOTE 3)	Non-GBR	7	100 ms (NOTE 1, NOTE 10)	10^{-3}	Voice, Video (Live Streaming) Interactive Gaming
8 (NOTE 5)	Non-GBR	8	300 ms (NOTE 1)	10^{-6}	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
9 (NOTE 6)	Non-GBR	9			
69 (NOTE 3, NOTE 9, NOTE 12)		0.5	60 ms (NOTE 7, NOTE 8)	10^{-6}	Mission Critical delay sensitive signalling (e.g., MC-PTT signalling, MC Video signalling)
70 (NOTE 4, NOTE 12)		5.5	200 ms (NOTE 7, NOTE 10)	10^{-6}	Mission Critical Data (e.g. example services are the same as QCI 6/8/9)
79 (NOTE 14)		6.5	50 ms (NOTE 1, NOTE 10)	10^{-2}	V2X messages
80 (NOTE 3)		6.8	10 ms (NOTE 10, NOTE 15)	10^{-6}	Low latency eMBB applications (TCP/UDP-based); Augmented Reality

NOTE 1: A delay of 20 ms for the delay between a PCEF and a radio base station should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface. This delay is the average between the case where the PCEF is located "close" to the radio base station (roughly 10 ms) and the case where the PCEF is located "far" from the radio base station, e.g. in case of roaming with home routed traffic (the one-way packet delay between Europe and the US west coast is roughly 50 ms). The average takes into account that roaming is a less typical scenario. It is expected that subtracting this average delay of 20 ms from a given PDB will lead to desired end-to-end performance in most typical cases. Also, note that the PDB defines an upper bound. Actual packet delays - in particular for GBR traffic - should typically be lower than the PDB specified for a QCI as long as the UE has sufficient radio channel quality.

NOTE 2: The rate of non congestion related packet losses that may occur between a radio base station and a PCEF should be regarded to be negligible. A PELR value specified for a standardized QCI therefore applies completely to the radio interface between a UE and radio base station.

NOTE 3: This QCI is typically associated with an operator controlled service, i.e., a service where the SDF aggregate's uplink / downlink packet filters are known at the point in time when the SDF aggregate is authorized. In case of E-UTRAN this is the point in time when a corresponding dedicated EPS bearer is established / modified.

NOTE 4: If the network supports Multimedia Priority Services (MPS) then this QCI could be used for the prioritization of non real-time data (i.e. most typically TCP-based services/applications) of MPS subscribers.

NOTE 5: This QCI could be used for a dedicated "premium bearer" (e.g. associated with premium content) for any subscriber / subscriber group. Also in this case, the SDF aggregate's uplink / downlink packet filters are known at the point in time when the SDF aggregate is authorized. Alternatively, this QCI could be used for the default bearer of a UE/PDN for "premium subscribers".

NOTE 6: This QCI is typically used for the default bearer of a UE/PDN for non privileged subscribers. Note that AMBR can be used as a "tool" to provide subscriber differentiation between subscriber groups connected to the same PDN with the same QCI on the default bearer.

NOTE 7: For Mission Critical services, it may be assumed that the PCEF is located "close" to the radio base station (roughly 10 ms) and is not normally used in a long distance, home routed roaming situation. Hence delay of 10 ms for the delay between a PCEF and a radio base station should be subtracted from this PDB to derive the packet delay budget that applies to the radio interface.

NOTE 8: In both RRC Idle and RRC Connected mode, the PDB requirement for these QCIs can be relaxed (but not to a value greater than 320 ms) for the first packet(s) in a downlink data or signalling burst in order to permit reasonable battery saving (DRX) techniques.

NOTE 9: It is expected that QCI-65 and QCI-69 are used together to provide Mission Critical Push to Talk service (e.g., QCI-5 is not used for signalling for the bearer that utilizes QCI-65 as user plane bearer). It is expected that the amount of traffic per UE will be similar or less compared to the IMS signalling.

NOTE 10: In both RRC Idle and RRC Connected mode, the PDB requirement for these QCIs can be relaxed for the first packet(s) in a downlink data or signalling burst in order to permit battery saving (DRX) techniques.

NOTE 11: In RRC Idle mode, the PDB requirement for these QCIs can be relaxed for the first packet(s) in a downlink data or signalling burst in order to permit battery saving (DRX) techniques.

NOTE 12: This QCI value can only be assigned upon request from the network side. The UE and any application running on the UE is not allowed to request this QCI value.

NOTE 13: Packet delay budget is not applicable on NB-IoT or when Enhanced Coverage is used for WB-E-UTRAN

NOTE 14: This QCI could be used for transmission of V2X messages as defined

NOTE 15: A delay of 2 ms for the delay between a PCEF and a radio base station should be subtracted from the given PDB to derive the packet delay budget that applies to the radio interface.

NOTE 16: For "live" uplink streaming guidelines for PDB values of the different QCIs correspond to the latency configurations defined in . In order to support higher latency reliable streaming services (above 500ms PDB), if different PDB and PELR combinations are needed these configurations will have to use non-standardised QCIs.

QCI	Resource Type	Priority Level	Packet Delay Budget (NOTE B1)	Packet Error Loss Rate (NOTE B2)	Maximum Data Burst Volume (NOTE B1)	Data Rate Averaging Window	Example Services
82 (NOTE B6)	GBR	1.9	10 ms (NOTE B4)	10^{-4} (NOTE B3)	255 bytes	2000 ms	Discrete Automation clause 8 bullet g, and table 7.2.2-1, "small packets")
83 (NOTE B6)	GBR	2.2	10 ms (NOTE B4)	10^{-4} (NOTE B3)	1354 bytes (NOTE B5)	2000 ms	Discrete Automation clause 8 bullet g, and table 7.2.2-1, "big packets")
84 (NOTE B6)	GBR	2.4	30 ms (NOTE B7)	10^{-5} (NOTE B3)	1354 bytes (NOTE B5)	2000 ms	Intelligent Transport Systems clause 8, bullet h, and table 7.2.2)
85 (NOTE B6)	GBR	2.1	5 ms (NOTE B8)	10^{-5} (NOTE B3)	255 bytes	2000 ms	Electricity Distribution- high voltage clause 8, bullet i, and table 7.2.2 and Annex D, clause D.4.2).

NOTE B1: The PDB applies to bursts that are not greater than Maximum Data Burst Volume.

NOTE B2: This Packet Error Loss Rate includes packets that are not successfully delivered over the access network plus those packets that comply with the Maximum Data Burst Volume and GBR requirements but which are not delivered within the Packet Delay Budget.

NOTE B3: Data rates above the GBR, or, bursts larger than the Maximum Data Burst Volume, are treated as best effort, and, in order to serve other packets and meet the PELR, this can lead to them being discarded.

NOTE B4: A delay of 1 ms for the delay between a PCEF and a radio base station should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface.

NOTE B5: This Maximum Data Burst Volume value is set to 1354 bytes to avoid IP fragmentation on an IPv6 based, IPSec protected GTP tunnel to the eNB (the value is calculated as in Annex C and further reduced by 4 bytes to allow for the usage of a GTP-U extension header).

NOTE B6: This QCI is typically associated with a dedicated EPS bearer.

NOTE B7: A delay of 5 ms for the delay between a PCEF and a radio base station should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface.

NOTE B8: A delay of 2 ms for the delay between a PCEF and a radio base station should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface.

PIN Definitions of terms and abbreviations

Personal IoT Network: A configured and managed group of PIN Element that are able to communicate each other directly or via PIN Elements with Gateway Capability (PEGC), communicate with 5G network via at least one PEGC, and managed by at least one PIN Element with Management Capability (PEMC).

PIN Element (PINE): A UE or Non-3GPP device that can communicate within a PIN (via PIN "direct" connection, via PEGC, or via PEGC and 5GC), or outside the PIN via a PEGC and 5GC.

PIN Element with Gateway Capability: A PIN Element with the ability to provide connectivity to & from the 5G Network for other PIN Elements, or to provide "relay" for the communication between PIN Elements.

PIN Element with Management Capability: A PIN Element with capability to manage the PIN.

NOTE: A PIN Element can have both PIN Management Capability and Gateway Capability.

PINE-to-PINE communication: communication between two PINEs which may use PINE-to-PINE direct communication or PINE-to-PINE indirect connection.

PINE-to-PINE direct connection: the connection between two PIN Elements without PEGC, any 3GPP RAN or core network entity in the middle.

PINE-to-PINE indirect connection: the connection between two PIN Elements via PEGC or via UPF.

PINE-to-PINE routing: the traffic is routed by a PEGC between two PINEs, the two PINEs direct connect with the PEGC via non-3GPP access.

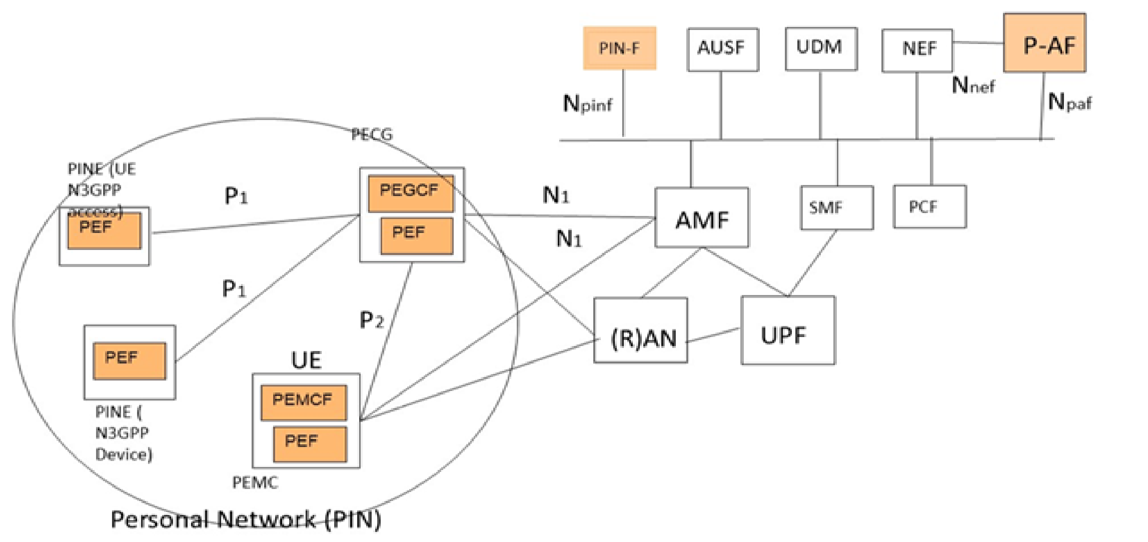
PINE-to-Network routing: the traffic is routed by a PEGC between PINE and 5GS, the PINE direct connects with the PEGC via non-3GPP access separately.

Network local switch for PIN: the traffic is routed by UPF(s) between two PINEs, the two PINEs direct connect with two PEGCs via non-3GPP access separately.

Abbreviations

PIN	Personal IoT Networks
PINE	PIN Element
PEGC	PIN Elements with Gateway Capability
PEMC	PIN Elements with Management Capability
P2P	PINE-to-PINE
P2N	PINE-to-Network
NLSP	Network Local Switch for PIN

Note 1: The AF relies on PIN signaling between the PINE/PEGC/PEMC and the PIN AF, which is transferred via UP transparently to the 5G System, to determine the need for a QoS modification.



5G System PIN Solution Reference Architecture

5G System (5GS) enhancements to support **Personal IoT Network (PIN).**

- Management of PIN,
- Access of PIN via PIN Element (PINE) with Gateway Capability (PEGC), and
- Communication of PIN (e.g. PINE (e.g. a UE) communicates with
    - other PINE (UE) "directly" or
    - via PEGC or
    - via PEGC and 5GS.

- Security related when identifying PIN and the PINE when:
    - How to identify PIN and the PINEs in the PIN at 5GC level to serve for Authentication& Authorization
    - Management as well as Policy and Routing Control enforcement:

- Management of a PIN.
- PIN & PINE Discovery

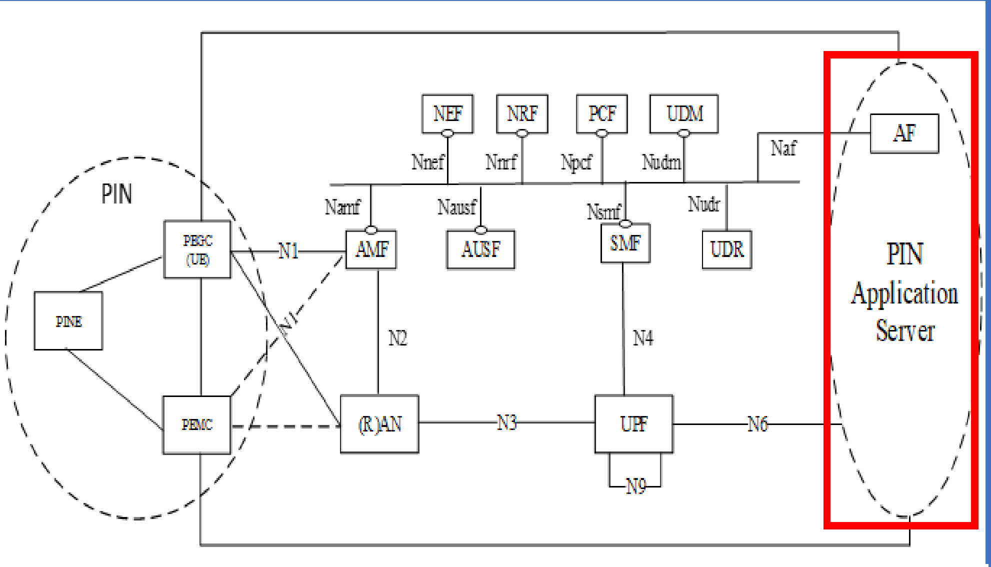


Figure: 5GS PIN Personal IoT Network Reference Architecture

A **Personal IoT Network (PIN**) in **5GC** consists of:

- 1 (one) or more Devices providing Gateway/Routing Functionality known as **the PIN Element with Gateway Capability (PEGC**), and

- 1 (one) or more Devices providing PIN Management Functionality known as the **PIN Element with Management Capability (PEMC**) to manage the Personal IoT Network; and

- Device(s) called the PIN Elements (PINE). A PINE can be a non-3GPP Device.

The PIN can also have a PIN Application Server (AS) that includes an AF (Application Function) functionality.

The AF can be deployed by Mobile Operator or by an Authorized Third (3rd) Party.

When the AF is deployed by 3rd Party, the interworking with 5GS is performed via the NEF.

The PEMC and PEGC communicates with the PIN Application Server (AS) at the Application Layer over the User Plane. The PEGC and PEMC can communicate with each other via "Direct" Communication

Only a 3GPP UE can act as PEGC and/or PEMC.

PINs and CPNs (Customer Premises Networks)

Personal IoT Networks (PINs) and Customer Premises Networks (CPNs) provide local connectivity between UEs and/or Non-3GPP Devices.

The CPN via an eRG, or PIN Elements (PINEs) via a PIN Element with Gateway Capability (PEGC) can provide access to 5G Network Services for the UEs and/or Non-3GPP Devices on the CPN or PIN.

CPNs and PINs have in common that, in general, they are:
- owned, Installed and/or (at least partially) Configured by a Customer of a Public Network Operator.

A Customer Premises Network (CPN) is a Network located within
- a Premises (e.g. a Residence, Office or Shop).
- via an evolved Residential Gateway (eRG), the CPN provides connectivity to the 5G Network. The eRG can be connected to the 5G Core Network via wireline, wireless, or hybrid access.
- A *Premises Radio Access Station* (**PRAS**) is a Base Station installed in a CPN. Through the PRAS, UEs can get Access to the CPN and/or 5G Network Services.

The **PRAS** can be configured to use
- Licensed,
- Unlicensed, or
- Both Frequency bands.

Connectivity between the **eRG** and the **UE**, **non-3GPP Device**, or **PRAS** can use any suitable **Non-3GPP Technology** (e.g. **Ethernet, optical, WLAN).**

A Personal IoT Network (PIN) consists of **PIN Elements (PINEs)** that communicate using PIN
- "Direct Connection" or
- "Direct Network Connection

and is managed locally using a PIN Element (PINE) with Management Capability (PEMC).

Examples of PINs include Networks of Wearables and Smart Home / Smart Office Equipment.

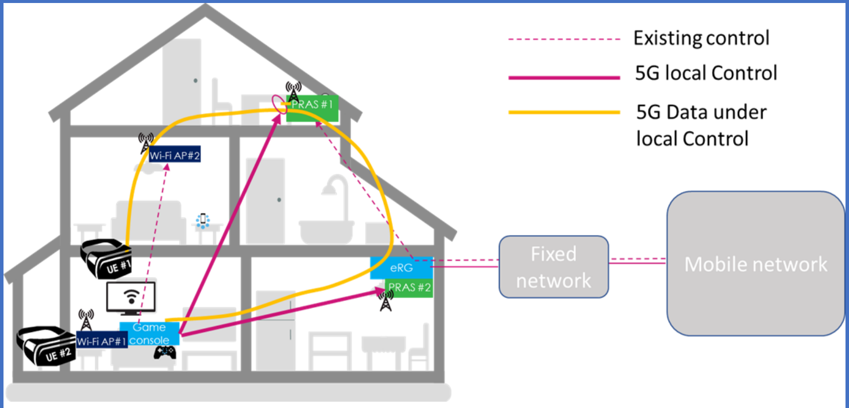


Figure: 5G Local Control of Premise Radio Access Stations (PRASs) for UE to access CPN Device

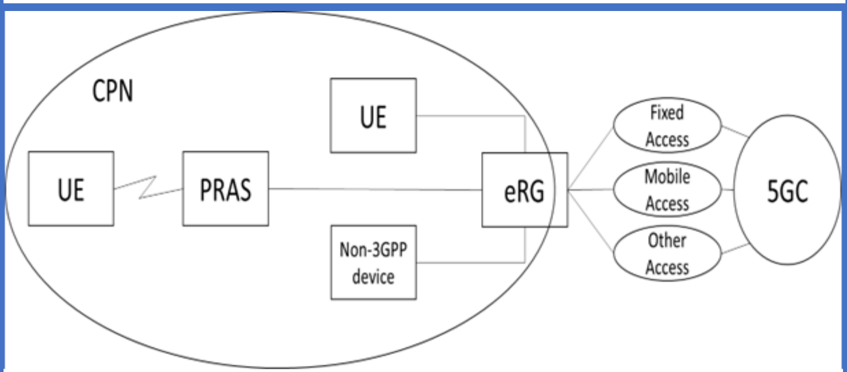


Figure: Customer Premises Network (CPN) connected to 5GC

Vodafone unveils Open RAN 5G network-in-a-box

Feb 17, 2023

Vodafone's Yago Tenorio shows off the operator's 5G network-in-a-box.

- Vodafone has unveiled a new mini 5G network the size of a Wi-Fi router
- It has a core and radio software, a mini computer and a software-defined radio chipset
- It is just a prototype currently
- But if offered as a product could revolutionise the 5G private network sector

5GS Configuration KIs (Key Issues) mapped to Solutions

Key Issue #5: Authorization for PIN

The Owner of a PIN may configure "Authorization Information for the PIN, e.g. whether a PINE can communicate with other PINEs or with a Specific Data Network (DN), whether a UE is allowed to act as a PEMC and/or a PEGC, etc.

Solution #0A: 5GC (Core) Architecture enhancements to support PIN

Solution #0B: PIN Architecture alternative "B"

Solution #0C: PIN Architecture alternative "C"

Solution #0D: Personal IoT Networks (PINs) Architecture in 5GS

Solution #2: PIN and PINE Discovery and Selection - this solution is based on the Architecture "alternative A" on Service Discovery based on "http".

Solution #4A: PIN and PIN Element (PINE) discovery by a PINE

Solution #4B: PIN Elements (PINE) with Gateway Capabilities (PEGC) "Discovery and Selection by PEMC (PIN Element with Management Capability).

Table : Mapping of Solutions to Key Issues

Solutions	Key Issues						
	1 5GC architecture enhancements to support PIN	2 PIN and PIN Element discovery and selection	3 Management of PIN and PIN Elements	4 Communication of PIN	5 Authorization for PIN	6 Policy and parameters provisioning for PIN	7 Identification of PIN and PIN Elements
0A	X						
0B	X						
0C	X						
0D	X						
0E	X						
1		X	X		X		X
2		X	X				
3		X					X
4A		X					
4B		X				X	
5			X	X	X	X	X
6			X		X		X
7			X	X		X	
8			X		X	X	X
9		X	X		X	X	X
10			X				
11				X			
12				X		X	X
13				X			
14		X				X	
15		X					
16				X			
17				X			
18				X			
19				X		X	
20			X	X			
21					X		
22					X		
23						X	
24						X	
25						X	
26						X	
27			X				X

5G System (5GS) PINs Architecture Application Layer PINAPP) Enhancements
Key Issues (KIs) mapped to Solutions

KI #1: PIN Management

KI #2: PINAPP accesses 5G Network by Application mechanism

KI #3: Service Switch in PIN

KI #4: PIN Application Server Discovery

KI #5: Service Continuity

KI #6: PEMC/PEGC replacement in PIN

Release 18 3GPP V18.1.0 (2023-03)

Solutions

Mapping of solutions to key issues

Table . .– Mapping of solutions to key issues

	KI #1	KI #2	KI #3	KI #4	KI #5	KI #6
Sol #1	X					
Sol #2	X					X
Sol #3	X					
Sol #4	X					
Sol #5	X					
Sol #6	X					
Sol #7	X					
Sol #8			X			
Sol #9						X
Sol #10			X			
Sol #11				X		
Sol #12	X					
Sol #13	X					
Sol #14		X				
Sol #15		X			X	
Sol #16	X					
Sol #17					X	

Release 18 3GPP V18.1.0 (2023-03)

PIN Profile in a PIN

Table : PIN Profile in PIN server, PEMC, PEGC and PINE

Parameter Name	Parameter Description	PIN Server	PEMC	PEGC	PINE
PIN ID	The identifier of the PIN	Y	Y	Y	Y
PIN Description	Human-readable description of the PIN, for example, the company name, location or the type of service.	Y	Y	Y	Y
Duration	Specifies the time period of how long the PIN can be active	Y	Y	Y	Y
Maximum number of PIN elements	Maximum number of PIN elements allowed to join the PIN	Y	Y	N	N
PIN service	List of service that a PIN can provide, including the PINE service or the service that can provided by application client on PINE: > PIN service Provider Identifier > PIN service type > PIN service Feature	Y	Y	N	Y
PEMC list	The list of identifiers of the PIN elements which can be allowed to take the role as PEMC (e.g.: PIN client ID, UE GPSI etc.,) and also it contains whether the role is primary or secondary	Y	Y	Y	Y
PEGC ID list	The list of identifiers of the PIN elements which can be allowed to take the role as PEGC (e.g.: PIN client ID, UE GPSI etc.,)	Y	Y	Y	Y
PIN Server ID	The identifier of the PIN server that serves the PIN	N	Y	Y	Y
PIN server Endpoint	Endpoint information (e.g. URI, FQDN, IP address) used to communicate with the PIN server.	N	Y	Y	Y
PIN Elements List	List of PIN elements which can be allowed to join the PIN > PIN element ID	Y	Y	Y	N

Dynamic profile information of a PIN

Table describes the list of parameters that are classified as dynamic profile information and which are maintained at the PIN server, PEMC and PEGC. Dynamic profile information maintained at these entities are updated based on the following events occurring in the PIN:

Mobile Networks to evolve from:

a Design that offers "Best-effort Services

to

a Design that offers Performance and User Experience Guarantees

=>

New Capabilities related to

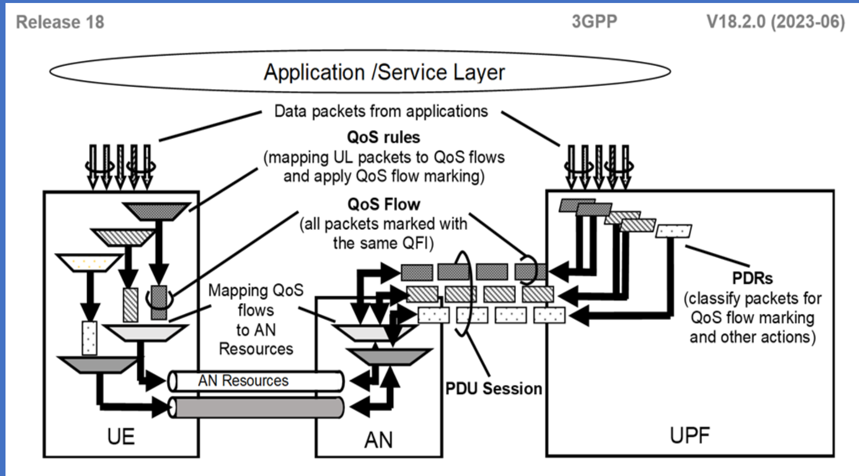


Figure: The 5G Principle for Classification and User Plane (UP) marking for QoS Flows and mapping to AN Resources

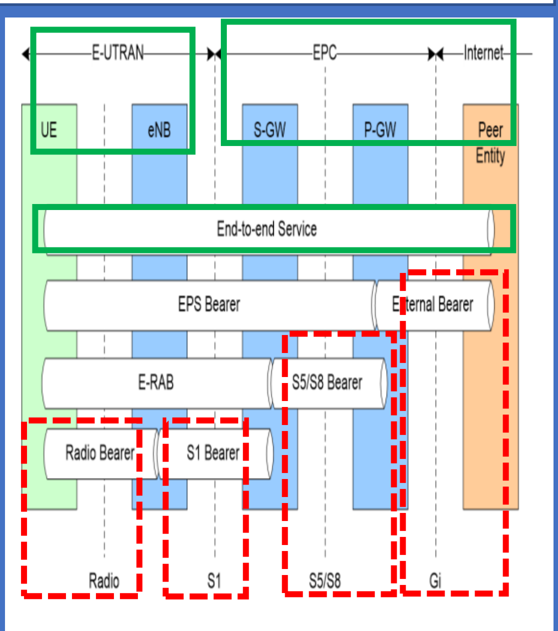


Figure : EPS Bearer Service Architecture

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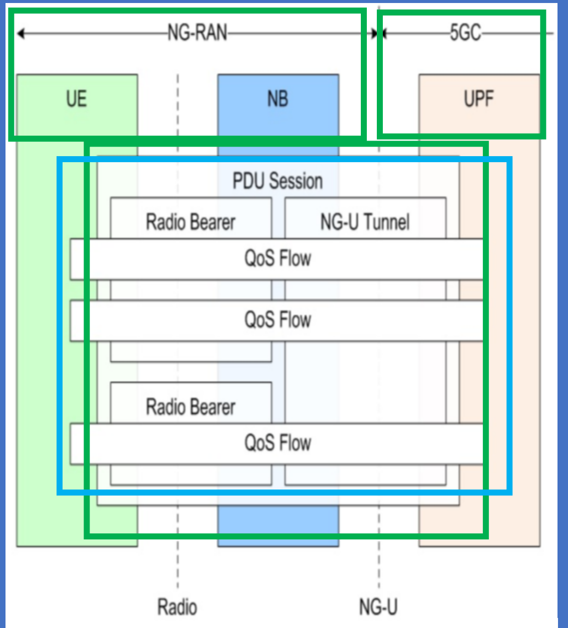


Figure: 5G CN NG-RAN Bearer Services QoS Architecture

5G PIN communication via PEGC and 5G System

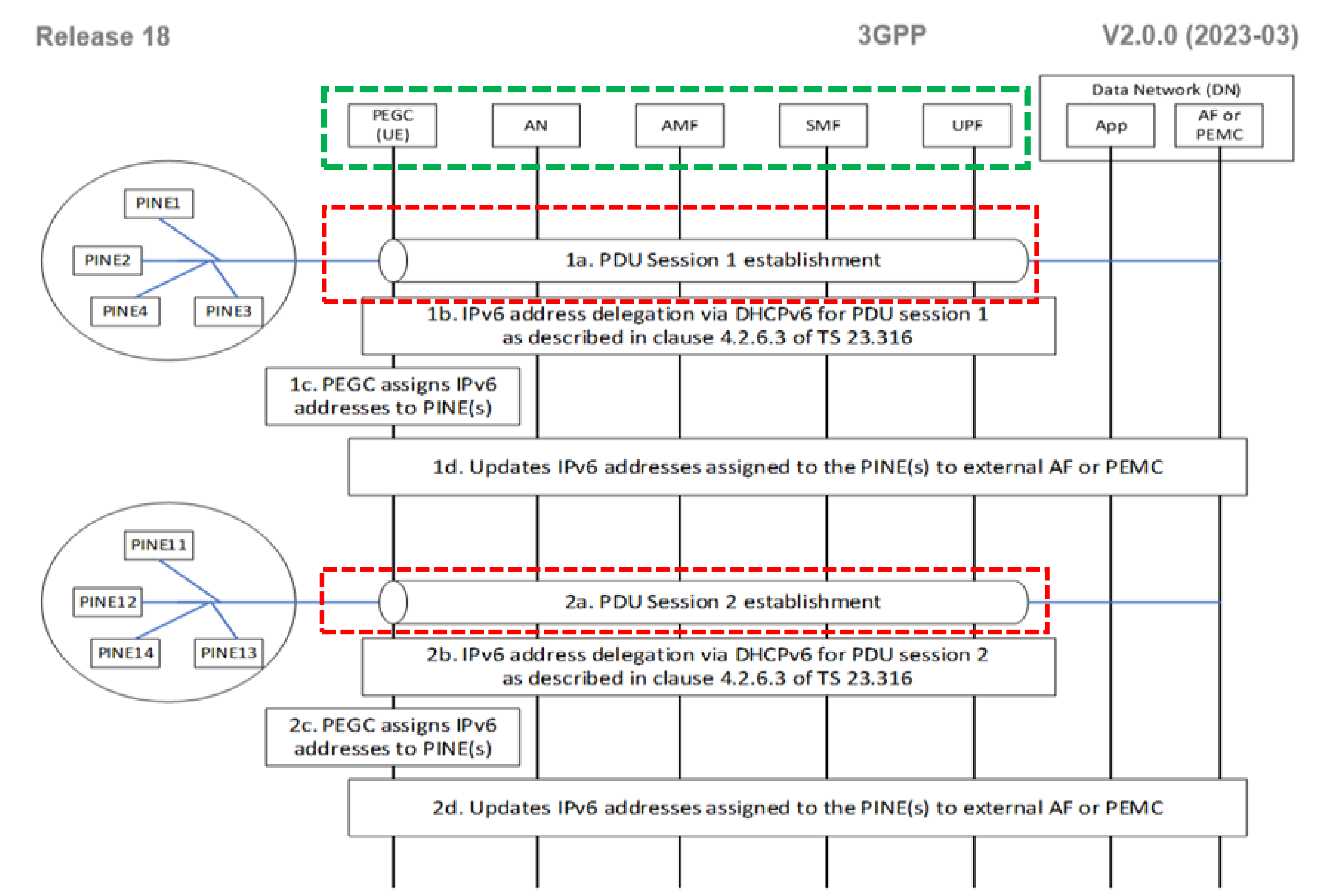


Figure: 5G PIN IPv6 address allocation to PINE by PEGC using IPv6 Prefix Delegation via DHCPv6

4 Architectural requirements and assumptions 4.1 Architectural Requirements

This study has following architectural requirements:

- If sidelink is used for the direct communication between PEMC and PEGC, reuse procedures defined for 5G ProSe Direct Communication without introducing new features to sidelink.
- There shall be no change to underlying non-3GPP access (e.g. WIFI, Bluetooth) standards.

4.2 Architectural Assumptions

This study has following architectural assumptions:

- **Only a 3GPP UE can act as PEGC and/or PEMC.**
- There are one or more PEGCs in a PIN.
- There are one or more PEMCs in a PIN, at any point of time one of which is able to control the PIN.
- **The PIN Elements assumes to use non-3GPP access (e.g. WIFI, Bluetooth) for direct communication, the PEMC can use 5G ProSe Direct Communication for direct communication with PEGC.**
- **In this release, the PEGC and PEMC belongs to same PLMN or (S)NPN.**
- The scenario when a PEGC or PEMC or both are in roaming is out of the scope of this release.
- A single PEGC may support more than one PIN at a time.
- Multi-hop P2P (i.e. communication between a chain of PINEs) and P2N relay (i.e. communication from a PINE to another PINE or to the network via an intermediate PINE) are not studied in this release.

Editor's note:Whether PINE can connect to multiple PEGCs is FFS.

NOTE: In this Release the 5G-RG is considered outside the scope of the study and consequently not part of PIN.

Editor's note:It is FFS whether data traffic of PINE over control plane is in scope of this study.

Editor's note:Whether PINE UE is restricted to be in the same PLMN/(S)NPN as PEGC/PEMC or not is FFS.

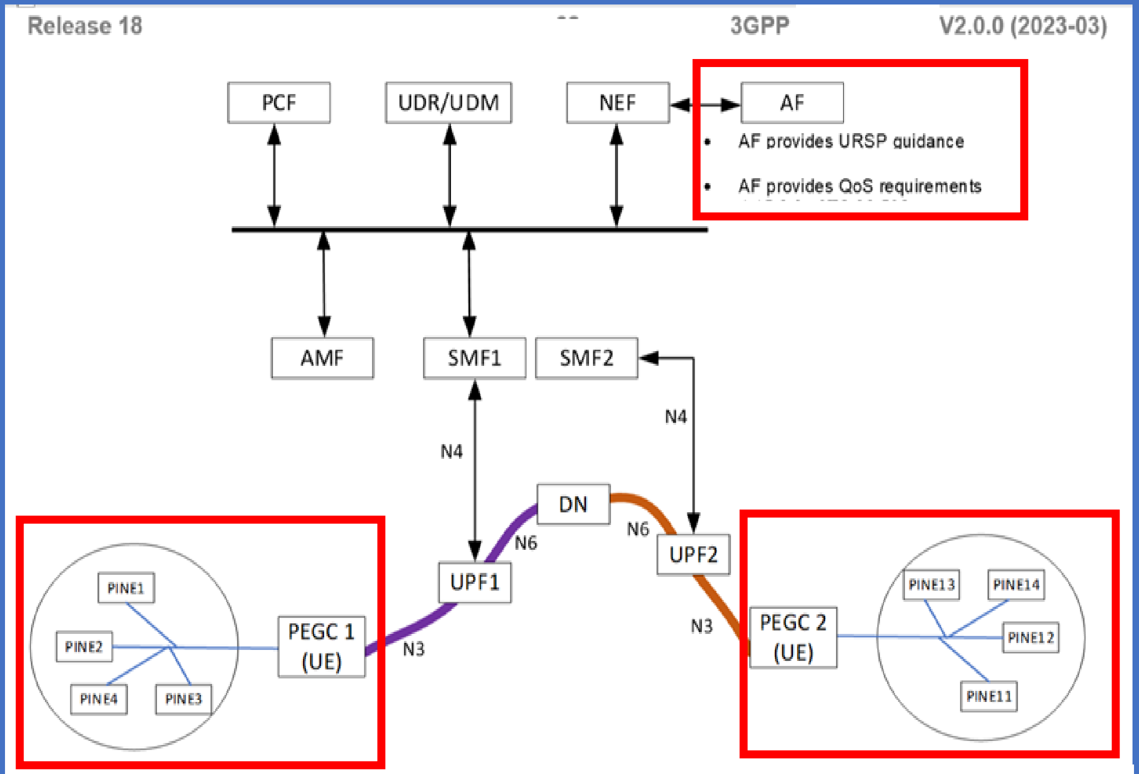


Figure: PINE Communication with 5G System

5G Advanced implementation of AI/ML Applications and ML Model Transfer Capabilities

In 5G, AI/ML is specified to be used in a range of Application Domains across Industry sectors. In 5G Mobile Communications Systems, Mobile Devices (e.g. Smartphones, Automotive, Robots) are increasingly replacing conventional algorithms (e.g. Speech Recognition, Image Recognition, Video Processing) with AI/ML Models to enable Applications. **The 5G System (5GS) can at least support three (3) types of AI/ML operations**: ***1. The UE Data Exposure Client (DEC)*** is responsible for sending *Data request to the Data Information AF* (**IEAF,** evolved Rel. 17 **DCAF/AF**) to collect Data from **NWDAF** as an input for **Application Layer AIML operation.** The **IEAF** is always in the MNO Domain & the **DEC** is based on **3GPP defined Procedures & Security &** *therefore is also under the control of MNO.* The Data Collection Request from UE Application may trigger the **IEAF** to collect Data from **NWDAF (IEAF deployment shown below). *2. AI/ML Model/Data Distribution & Sharing over 5GS*** (the Model Performance at the UE needs to be monitored constantly). ***3. Distributed/Federated Learning (FL) over 5GS*** (The Cloud Server trains a Global Model by aggregating Local Models partially-trained by each End Device via 5G UL). The Server aggregates the Interim Training results from the UEs & updates the Global Model. The Updated Global Model is then distributed back to the UEs & the UEs can perform the Training for the Next Iteration. Based on Operator Policy, 5GS shall be able to provide means to predict & expose predicted Network Condition changes (i.e. Bitrate, Latency, Reliability) per UE, to an Authorized 3rd Party. **Subject to User Consent, Operator Policy & Regulatory Constraints**, the 5GS shall be able to support **a Mechanism** to expose Monitoring & Status Information of an AI-ML Session to a 3rd Party AI/ML Application & be able to expose information (e.g. candidate UEs) to an Authorized 3rd Party to assist the 3rd Party to determine Member(s) of a Group of UEs (e.g. UEs of a FL Group). ***Depending on Local Policy or Regulations, to protect the Privacy of User Data, the Data Collection, ML Model Training & Analytics generation for a Subscriber/User id, Internal or External_Group_Id or "any UE" may be subject to User Consent*** bound to a Purpose, such as Analytics or ML Model Training. **The User Consent is "Subscription Information**" stored in the 5G CN, which includes: **A)** whether the User authorizes the Collection & Usage of its Data for a Particular Purpose; **B)** the **Purpose** for Data Collection, e.g. **Analytic or Model Training.**

5GS (System) proposes a Common **Solution Framework** to assist various Application AI/ML Operations with Assistance Info & Procedures from 5GC. In this Framework, the similar **Service Requirements & Operational behaviours** are organized into various *Application AI/ML Assistance* (**AaaML**) *Service Profiles* where *Each Profile defines specific AaaML Service*. The **AaaML Services** are a Set of Collective Extensions to the existing 5GC Services & the new 5GC Services which are defined specifically to assist the Application Layer AI/ML Service Operation. An **AaaML Service Profile** is composed of 3 main parts of information: A) **Objective** of Target AaaML Operation; **B) Input of Provisioned Service Parameter(s) (** e.g. Minimum One Way Delay, Predicted QoS Performance within the next 5 min.; **C) Output** (*e.g. List of Candidate UEs, Event Report for the Group of UE's Bandwidth Consumption.*

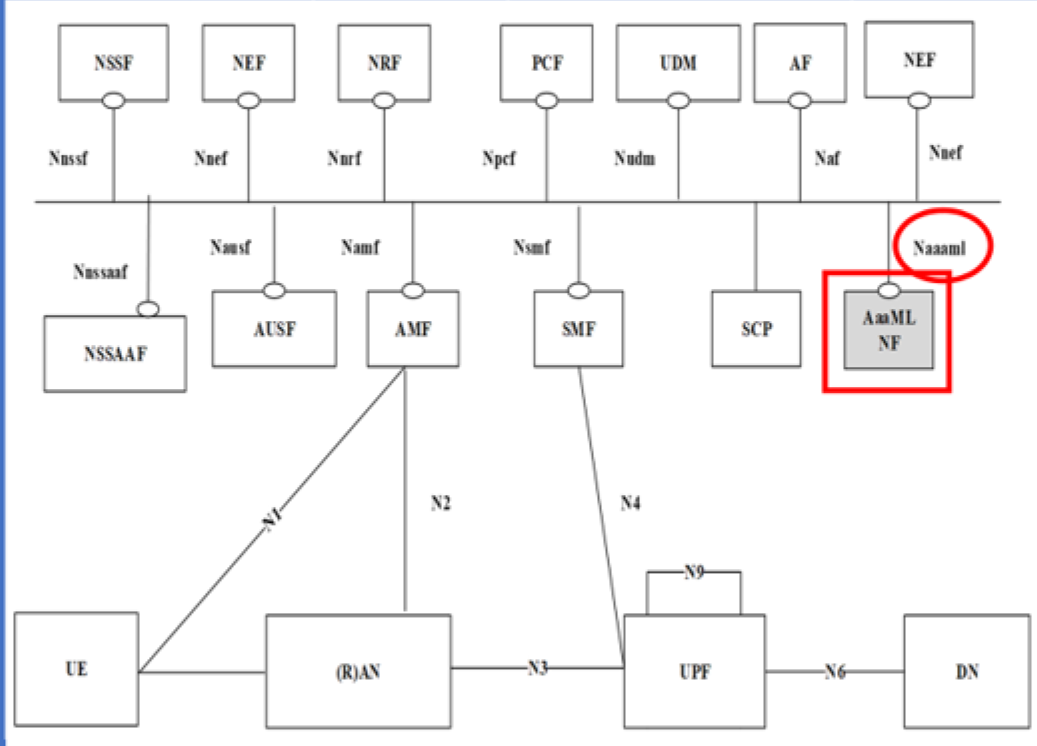


Figure: 5G System Service Architecture with AaaML NF

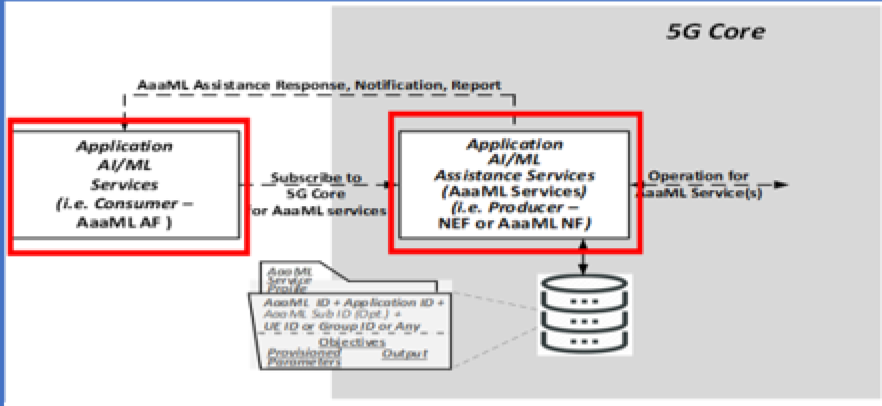


Figure: 5G Application AI/ML Service Assistance Framework

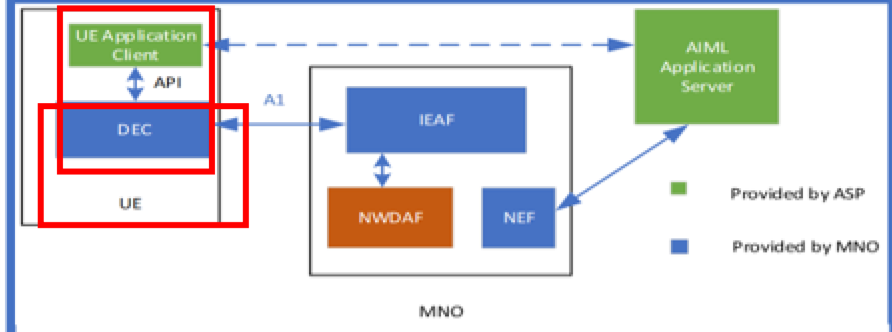


Figure: 5G IEAF (Data Information AF)

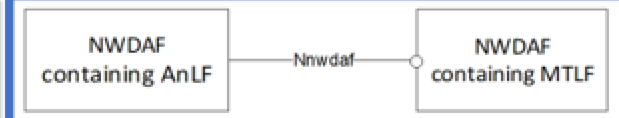


Figure: 5G NWDAF containing AnLF (Analytics Logical Function) for request and subscribe to ML Model Provisioning Architecture

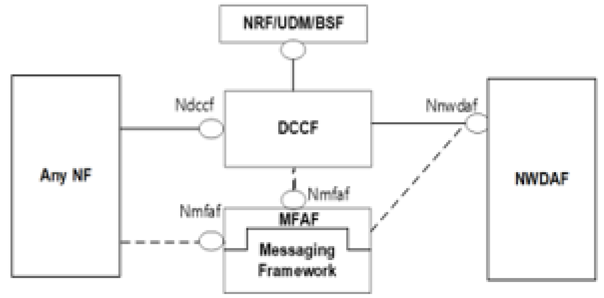


Figure: 5G Network Data Analytics Exposure Architecture using DCCF

Table: 5G NFs Consumed by DCCF or NWDAF to determine which NF instances are serving UE

Type of NF instance (serving the UE) to determine	NF to be contacted by DCCF	Service
UDM	NRF	Nnrf_NFDiscovery
AMF	UDM	Nudm_UECM
SMF	UDM	Nudm_UECM
BSF	NRF	Nnrf_NFDiscovery
PCF	BSF	Nbsf_Management
NEF	NRF	Nnrf_NFDiscovery
NWDAF	UDM	Nudm_UECM

A Current Smart Home IoT Deployment example

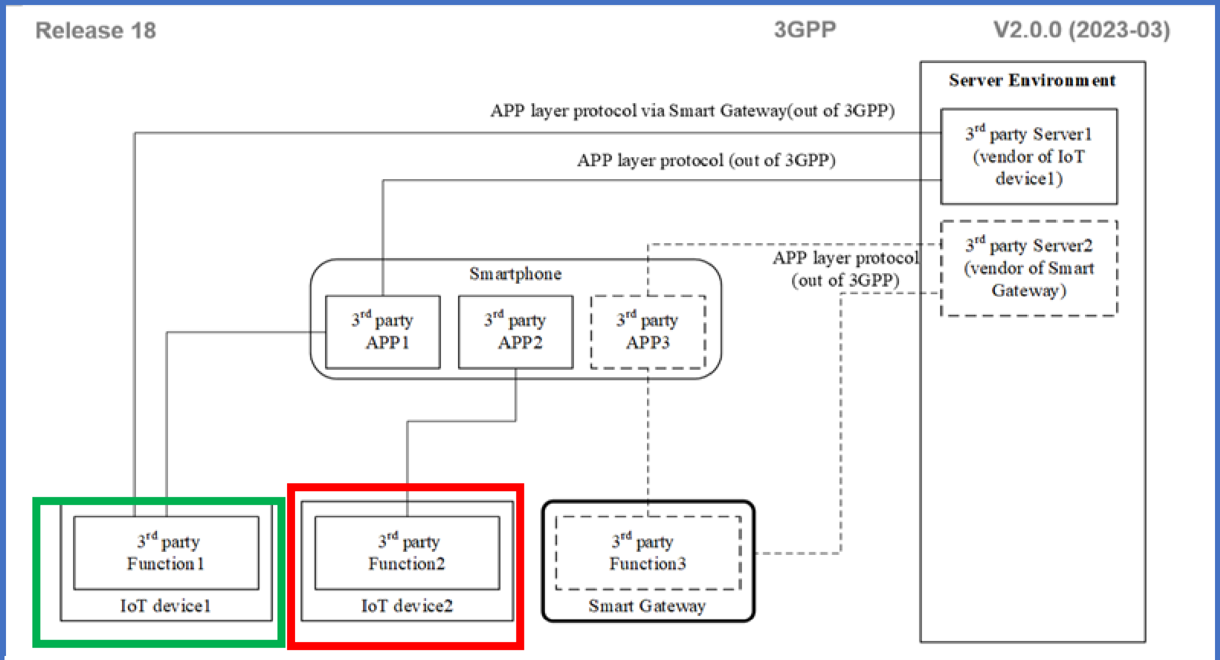


Figure: Example of Current IoT Smart Home Deployment

The IoT Device1 is initially discovered by a Smartphone using the 3rd Party APP1 installed in the Smartphone, and then the Smartphone is able to connect with the IoT Device1 assisted by the 3rd Party APP1.

The 3rd Party APP1 is developed by the Vendor of the IoT Device1. The IoT Device1 is able to visit the 3rd Party Server1 over Internet via the Smart Gateway, and the 3rd Party APP1 also can visit the 3rd Party Server1 over Internet, so that the Smartphone is able to control the IoT Device1 via internet assisted by the 3rd Party Server1.

The IoT Device2 is manufactured by a different Vendor from that of the IoT Device1, and is not able to be controlled by a Smartphone via Internet.

A 5G PIN Smart Home deployment example of the PIN that the PINMF can be a NF, Trusted AF, or 3rd Party AF.

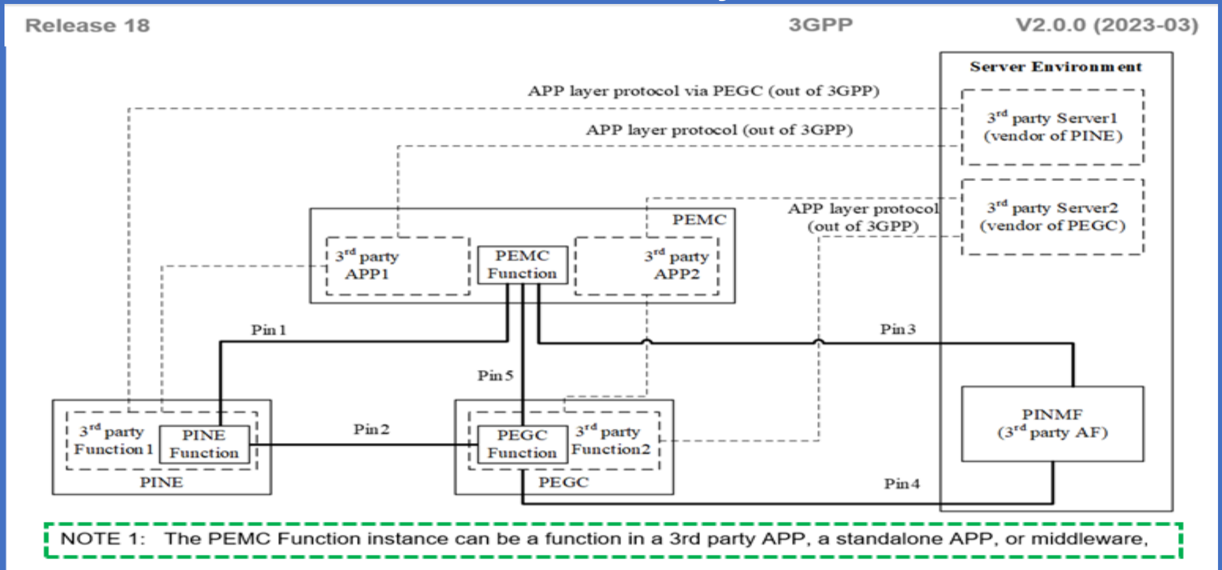


Figure: 5G PIN Deployment Functions Example

For the case of NF/trust AF, one Operator only has one (1) PINMF, the PEMC can use pre-configured information for PIN Service Operations, e.g. FQDN of the Operator's PINMF.

The 5GC uses External Group ID and Internal Group ID to identify the "Trust Member" Group.

The User's PIN related Subscription(s), which includes PEMCs and/or PEGCs, is considered as PIN "Trust Member(s)". If a PEGC is included in the Trust Members group, e.g. the User also subscribes the Smart Home GW as a "Trust Member", the Authorization of the PEGC is based on the Subscription, otherwise the Authorization of the PEGC is based on the request from the PEGC.

The Trust Members facilitate user to share PIN Management among multiple PEMCs. An example of the Trust Members is multiple Phones of the User for Wearable Cases, Family Members for Smart Home Cases, Partner Members for Smart Office Cases.

The User can assign additional PEMCs from the "Trust Members" to a PIN. With multiple PEMCs option, the User can pick up any Smart Phone to manage the PIN that only includes Wearable Devices, or any Family Member of the User can buy a New Device and update the PIN, which only includes Devices in Living Room, to add the New Device in the PIN without waiting the User back Home, etc.

For the Case of 3rd Party AF, there may be multiple PINMFs, which one is used is determined by the User, and the Serving PINMF should register itself for the User to handle the PIN Service Operations. An example of the UC with the deployment example is as following:

A Deployment Example of the PIN that the PINMF can be a NF, Trusted AF, or 3rd Party AF.

1) The PINE/PEGC establishes direct connection with the PEMC assisted by the 3rd party APP1/APP2 and 3rd party Function1/Function2, which is the same as currently widely used, or by user input.

2) If the PEMC Function instance obtains the Device metadata via the direct connection, e.g. MAC address, Vendor name, PINE Function Address, etc. from PINE Function (Pin1) over direct connection, or Device metadata, e.g. MAC address, GPSI, Vendor name, PEGC Function Address, etc. from PEGC Function (Pin5) over direct connection. The PEMC Function instance registers the Device metadata to the PINMF (Pin3). The <Vendor Name> helps the PEMC to run the APP developed by the Vendor to control the PINE, e.g. turn on/off a light, tune the temperature of an air conditioner, etc. The PINE/PEGC Function Address makes it possible for any PEMC Function instance (e.g. when User changes Cell Phone) to interact with the PINE/PEGC Function over direct connection (Pin1/Pin5), via PEGC (Pin1), via 5GS (Pin5), or via PEGC and 5GS (Pin1).

3) Any PEMC Function instance requests the PINMF to create a PIN and obtains Device information, which includes the address of PINE/PEGC Function, from PINMF (Pin3), the Device may already be added into another PIN. The PEMC Function instance requests the PINMF to add any Device into the PIN (Pin3).

4) When adding a UE into the PIN to act as PEGC, if the UE identified by the GPSI is pre-configured in the Subscription Data to be a PEGC, the PINMF configuring <allowed list>/<block list> to the PEGC (N1) for the PIN, if not, the PINMF returns <Registration URI> to the PEMC Function instance (Pin3), and the PEMC Function instance sends the URI to the PEGC Function (Pin5), the PEGC Function sends Registration Request to the PINMF (Pin4) to request the PINMF configuring <allowed list>/<block list> to the PEGC (N1) for the PIN;

5) The PEMC Function instance obtains the SSID/BT ID and Password of PEGCs from PINMF for the PIN (Pin3) and sends them to the PINE (Pin1) for configuring the PINE for discovery (PINE is listener), or obtains the SSID/BT ID and Password of PINEs from PINEs (Pin1) and sends them to the PINMF (Pin3) to request the PINMF configuring the PEGC (N1) for discovery (PINE is announcer);

6) After a PINE has been configured by the PEMC Function instance (Pin1) to associated with PEGCs, the PINE connects to a PEGC to activate association with the PEGC in the PIN. If the PINE has active association in another PIN, the PINE will be automatically removed from that PIN.

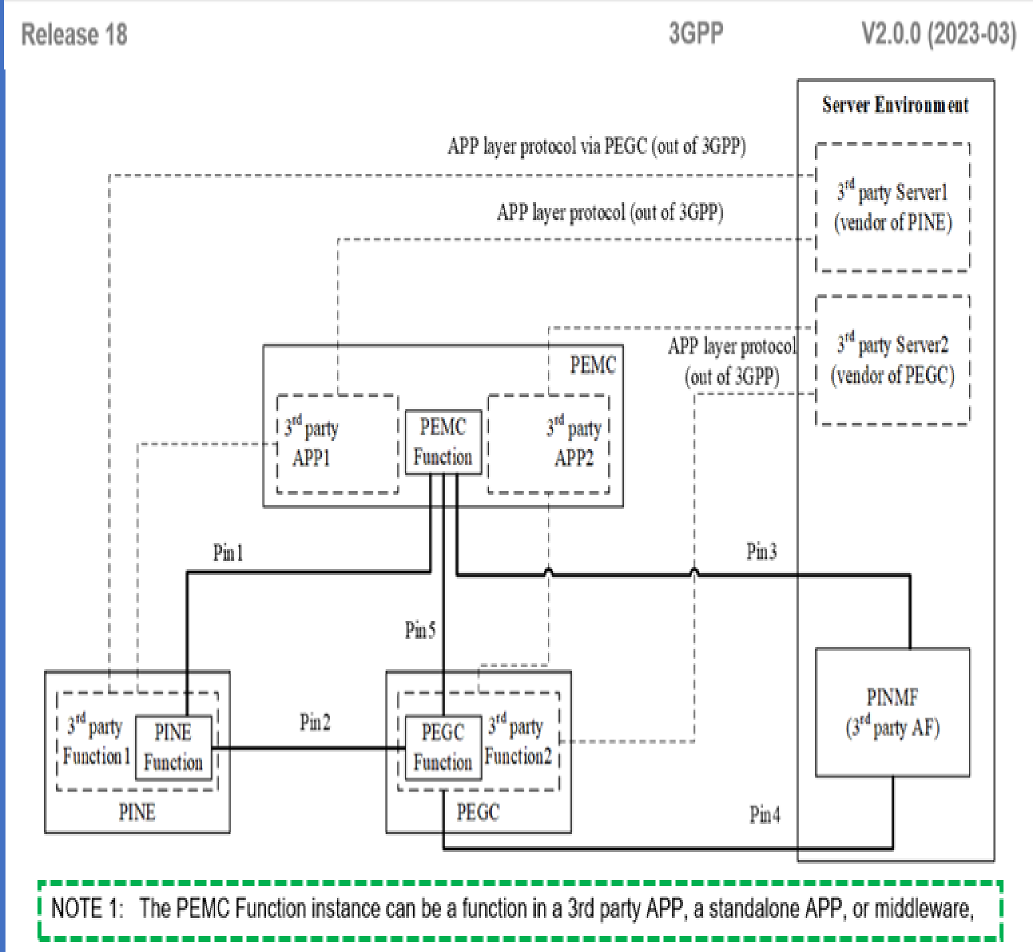
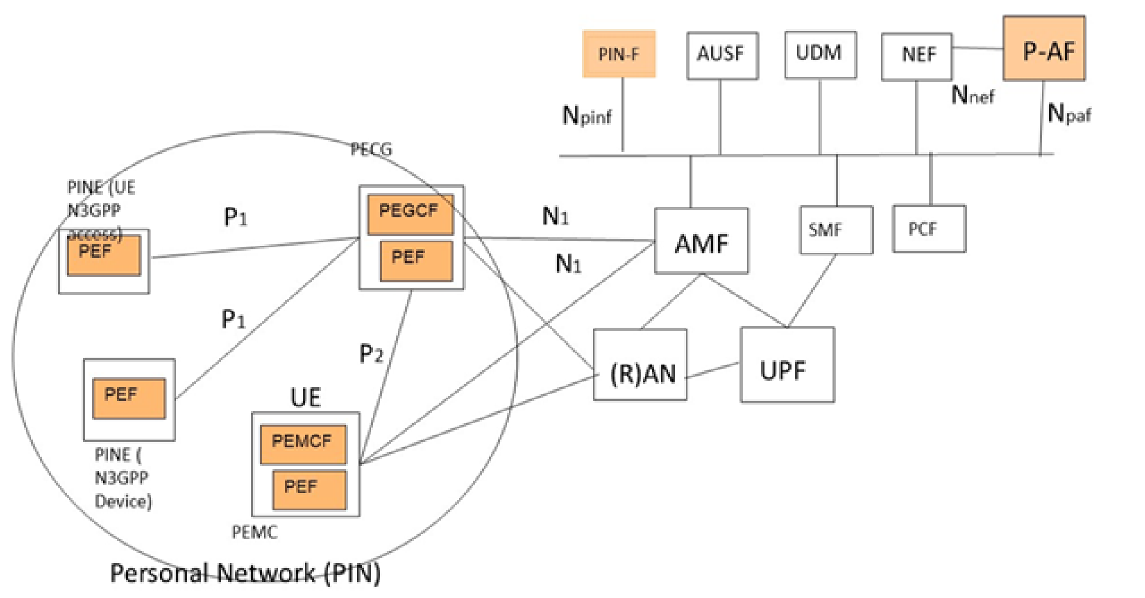


Figure: 5G PIN Deployment Functions Example

7) When the 3rd party APP on PEMC needs to communicate with PINEs, the PEMC Function sends the packet filters and necessary information to the PINMF (Pin3), the PINMF determines that the PINE has connected to a PEGC and instructs the 5GS to configure the PEGC for the relay, as well as instructs 5GS to establish a 5G-LAN that includes the PEMC and the PEGC, or add the PEMC and PEGC into the existed 5G-LAN, so that the communication does not need any Application Server for routing, which resolves the user concern related to privacy issues.

8) When the PINE needs to communicates with other PINEs, the PINE Function sends the packet filters and necessary information to the PEMC Function instance (Pin1), if the PEMC Function instance allows the communication, it requests the PINMF (Pin3) to configure PEGC(s) for the relay, and if multiple PEGCs involved, the PINMF instructs 5GS to establish a 5G-LAN that includes the PEGCs, or add the PEGCs into the existed 5G-LAN, so that the communication does not need any AS for routing, which resolves the user concern related to privacy issues.

5G System PIN Solution Reference Architecture



5G System PIN Solution Reference Architecture

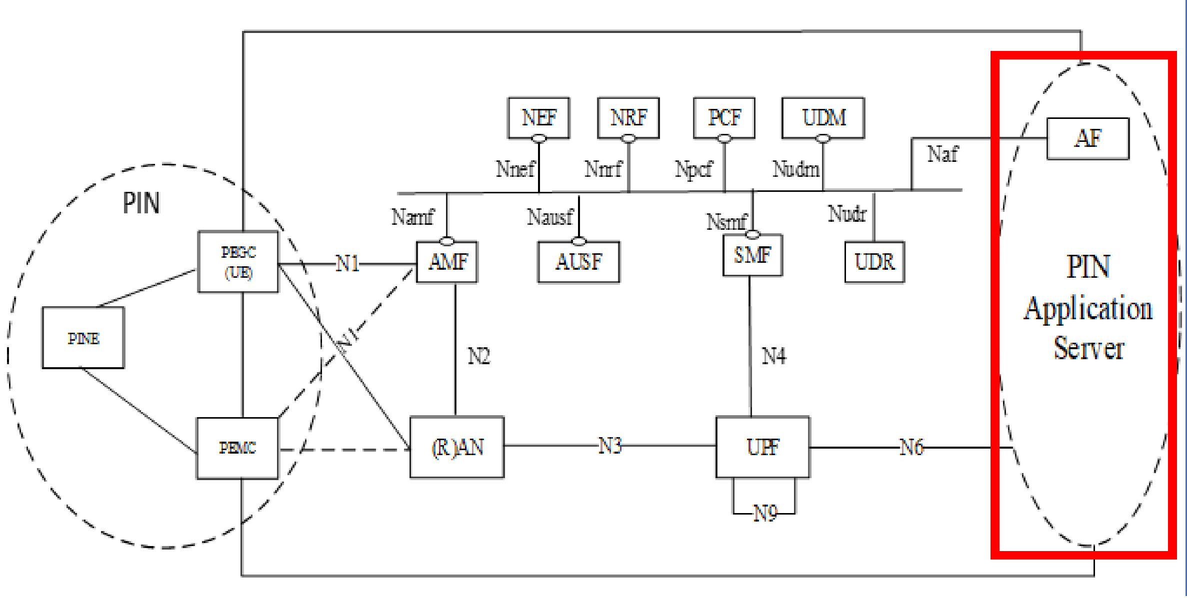


Figure: 5GS PIN Personal IoT Network Reference Architecture

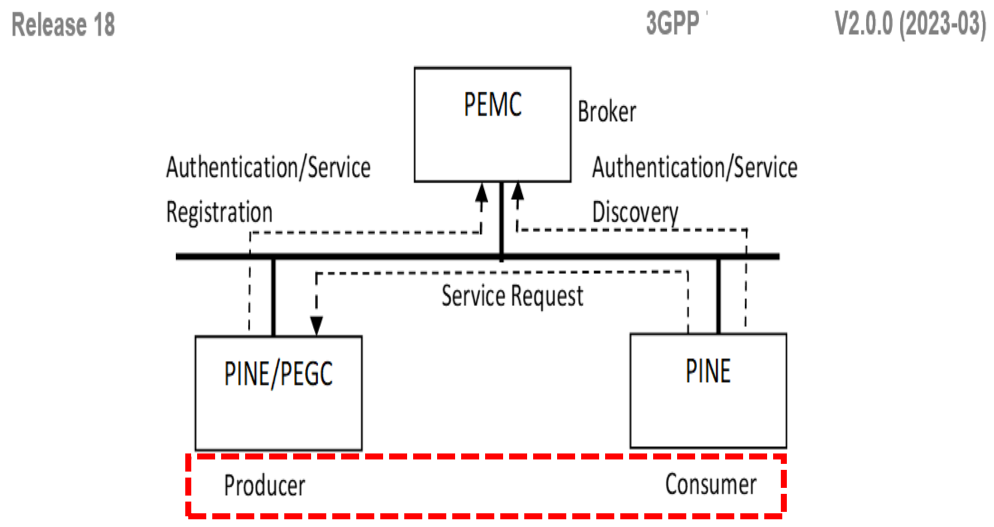


Figure: 5G SBA Architecture for Personal IoT Network (PIN)

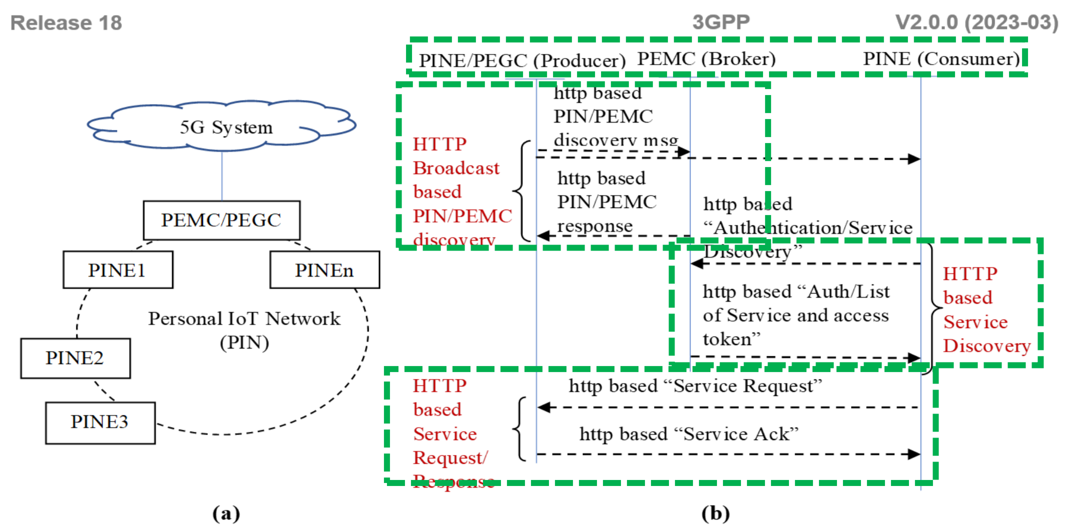


Figure: 5G PIN and PIN element (PINE) Discovery and Selection

Solution #2: PIN and PINE Discovery and Selection

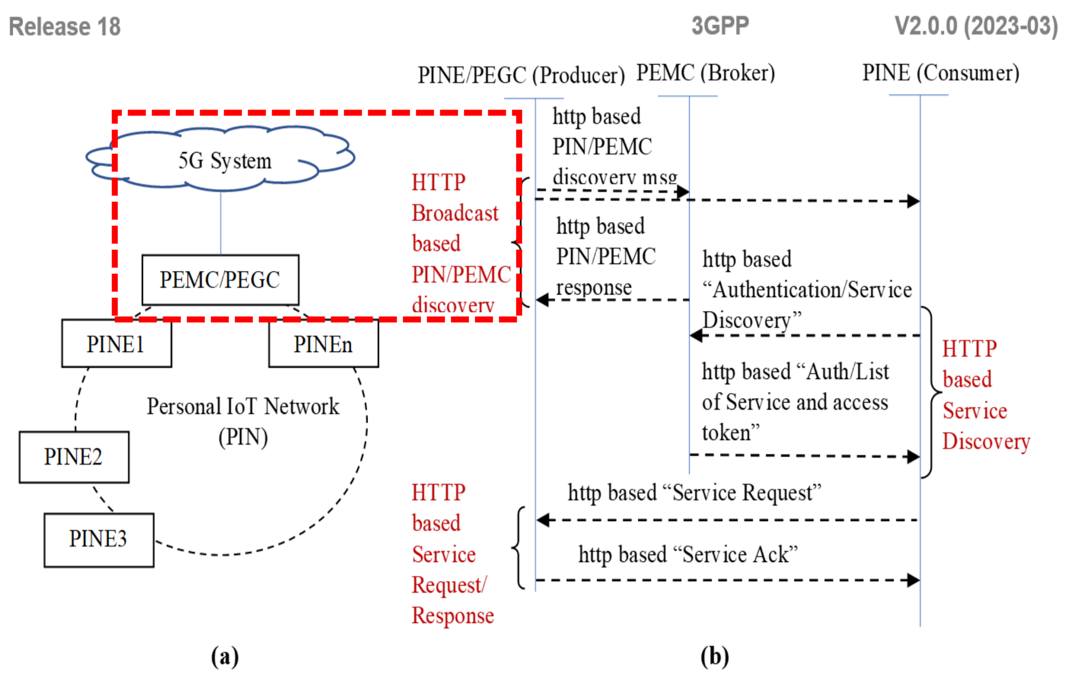


Figure: 5G PIN and PIN element (PINE) Discovery and Selection

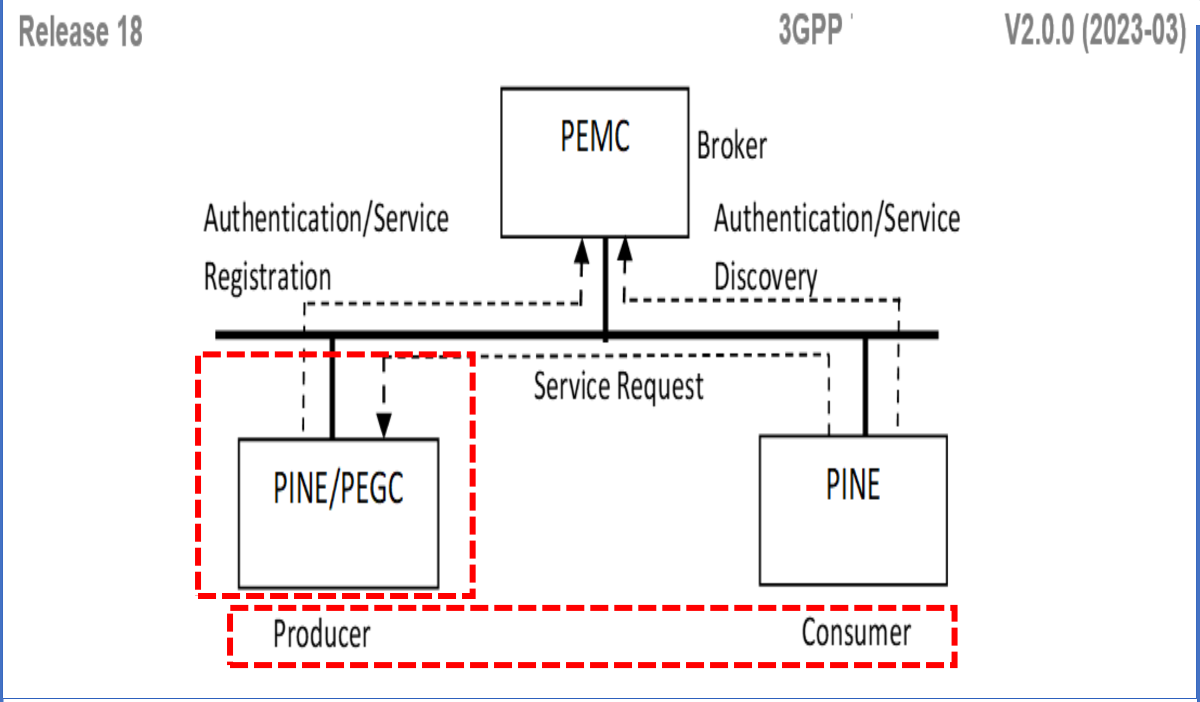


Figure: 5G SBA Architecture for Personal IoT Network (PIN)

PEMC Identification:
A NAS capable UE will register with the 5GS with "PIN capable" in the initial registration message to be authorized to form the PIN.

5GC (5G Core) Architecture enhancements to support PIN are described in the Solution for KI#1.

Based on the "PIN Control Function" Policies, the 5G Core will authorize/deny the PIN formation. PIN Element (PINE) is identified as PEMC either by the 5GC Policies or by 3rd Party Configuration.

A *PIN Element with Management Capability* (**PEMC**) can form a PIN and it can name the PIN based on the configuration.

PEMC of the PIN will act as a "broker" in the 5G PIN SBA Architecture and respond to the PIN discovery query by the PINE or PEGC as shown in Figure (a).

PEMC will be "NAS capable", and the Policies and its Capabilities are configured by the 5G Core Network. Policy and Provisioning for PIN are further described in the Solution for KI# Configuration.

5G PIN CP (Control Plane) Signalling Path and PINs UP (User Plane) Path

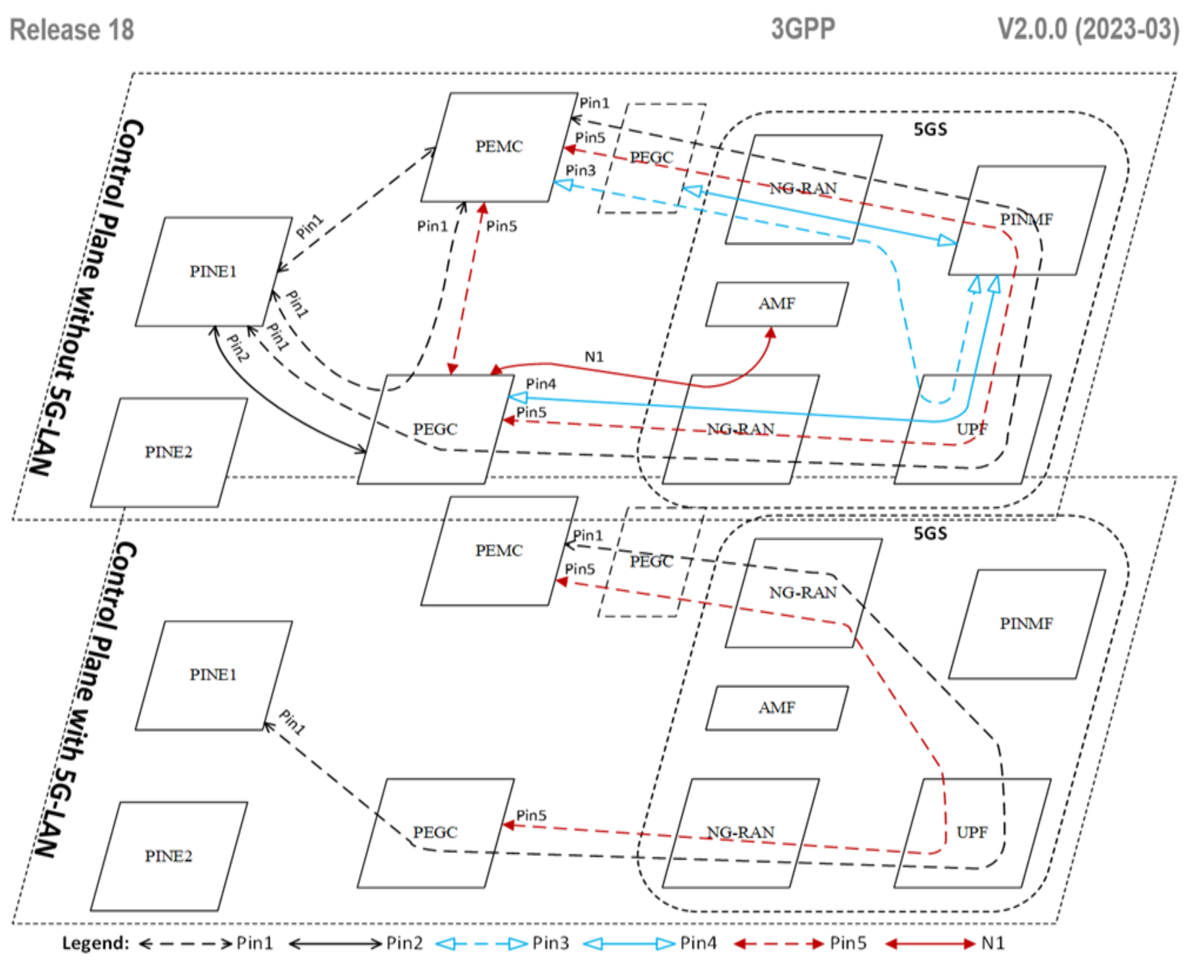


Figure: 5G PIN Control Plane (CP) Signalling Path with and without 5G-LAN

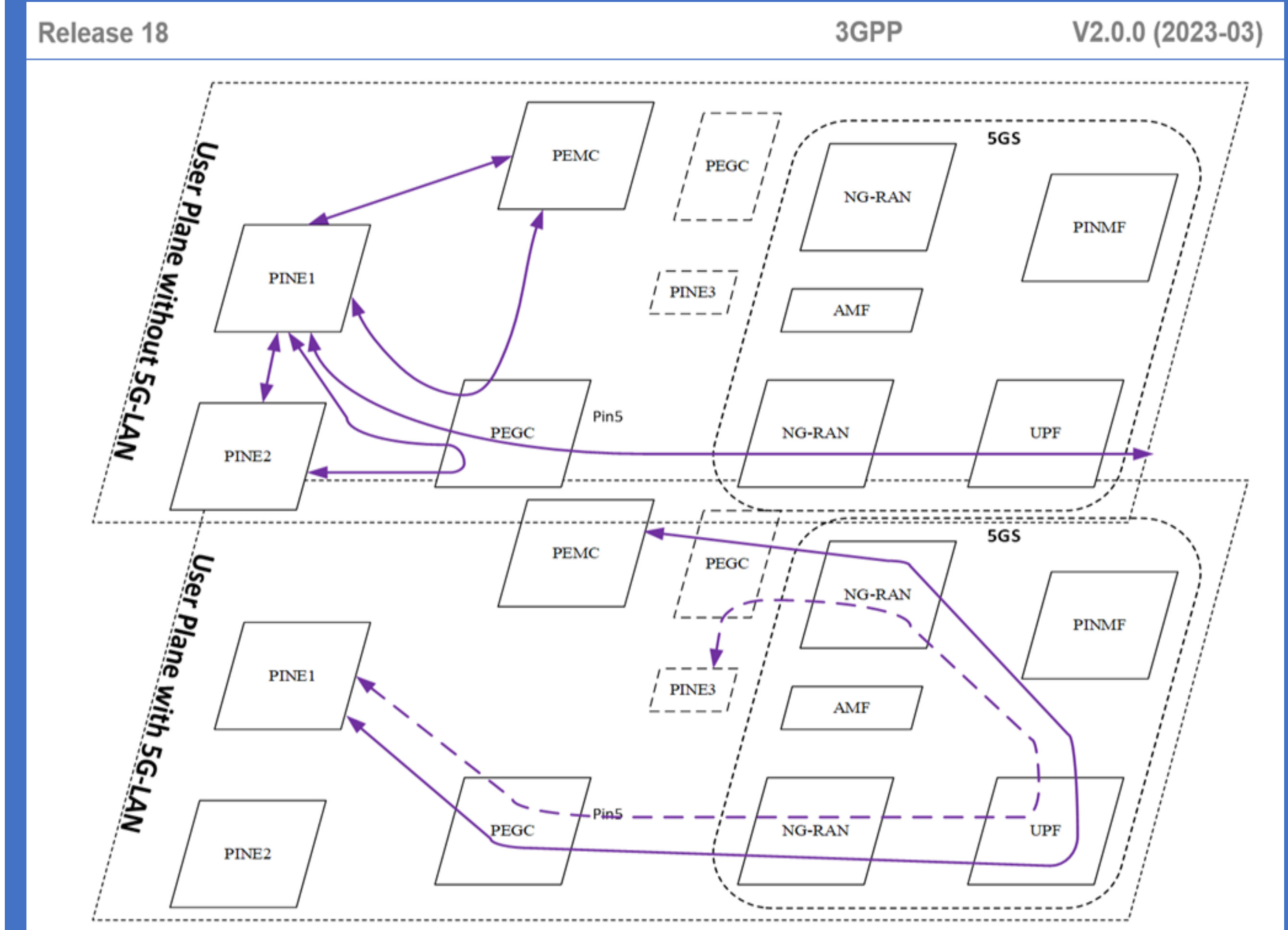
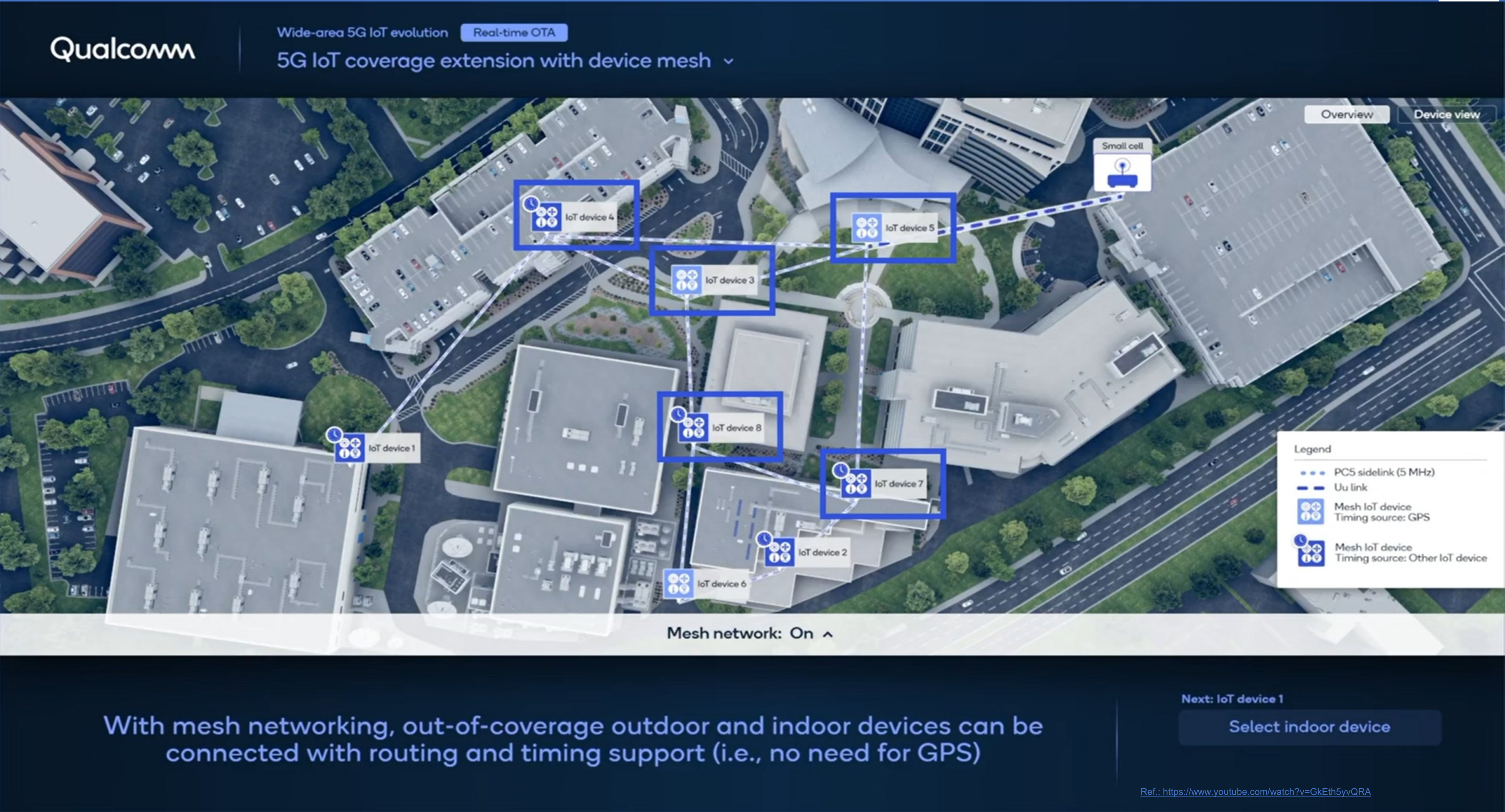


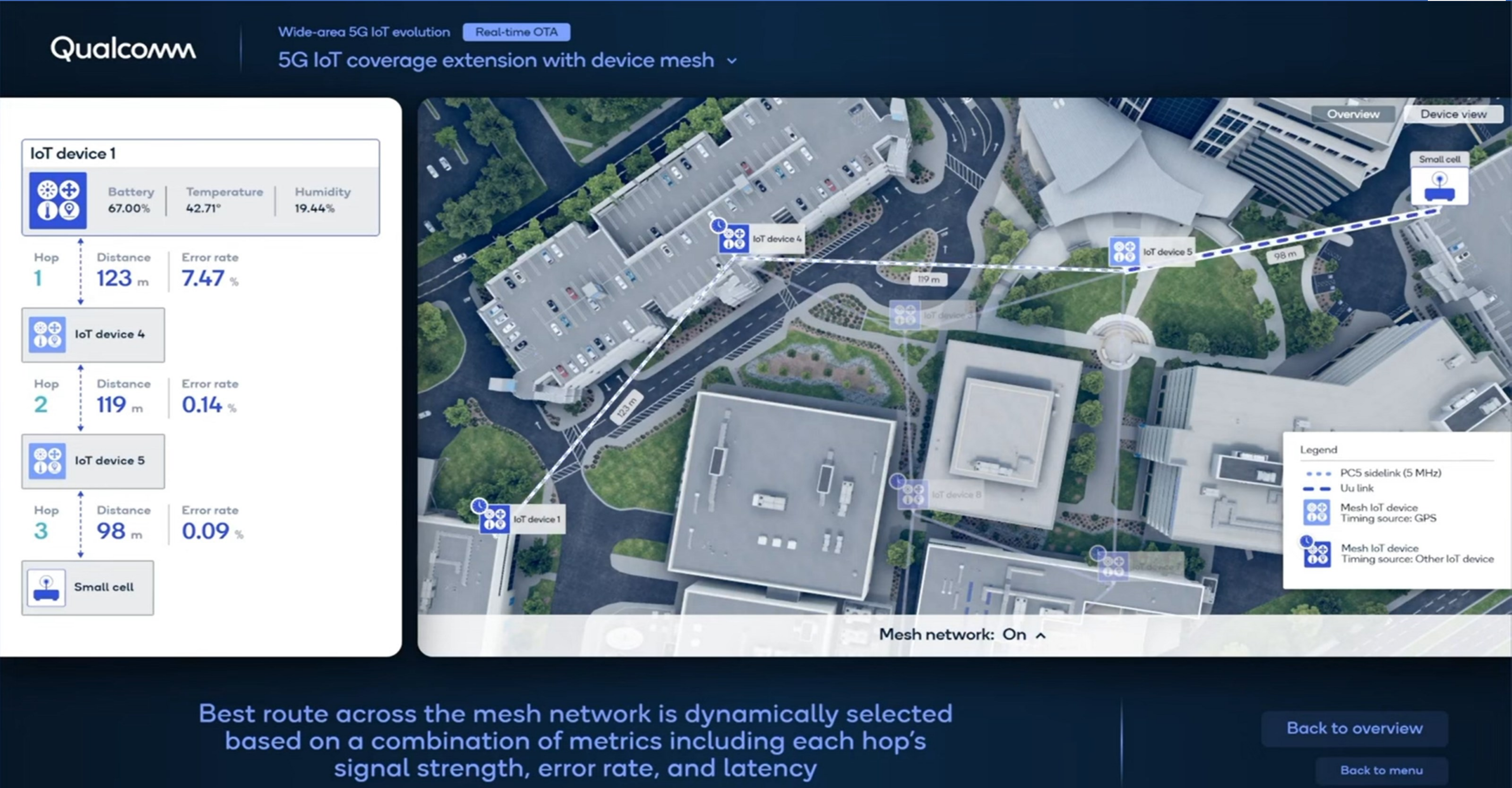
Figure: 5G PIN User Plane (UP) with and without 5G-LAN

Qualcomm 5G PINs Demo Presentation from MWC 2023 - 1



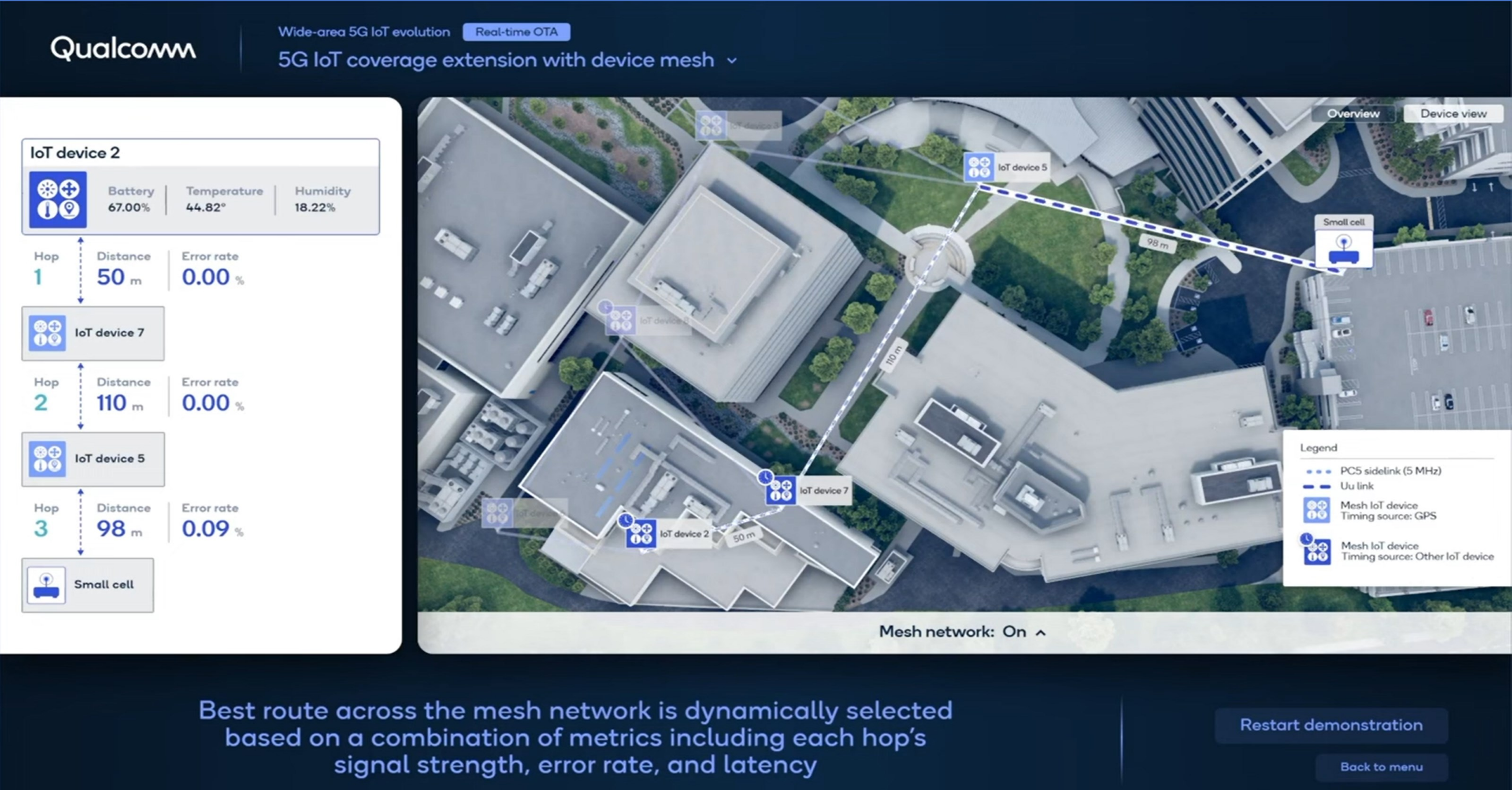
Ref.: https://www.youtube.com/watch?v=GkEth5yvQRA

Qualcomm 5G PINs Demo Presentation from MWC 2023 - 2



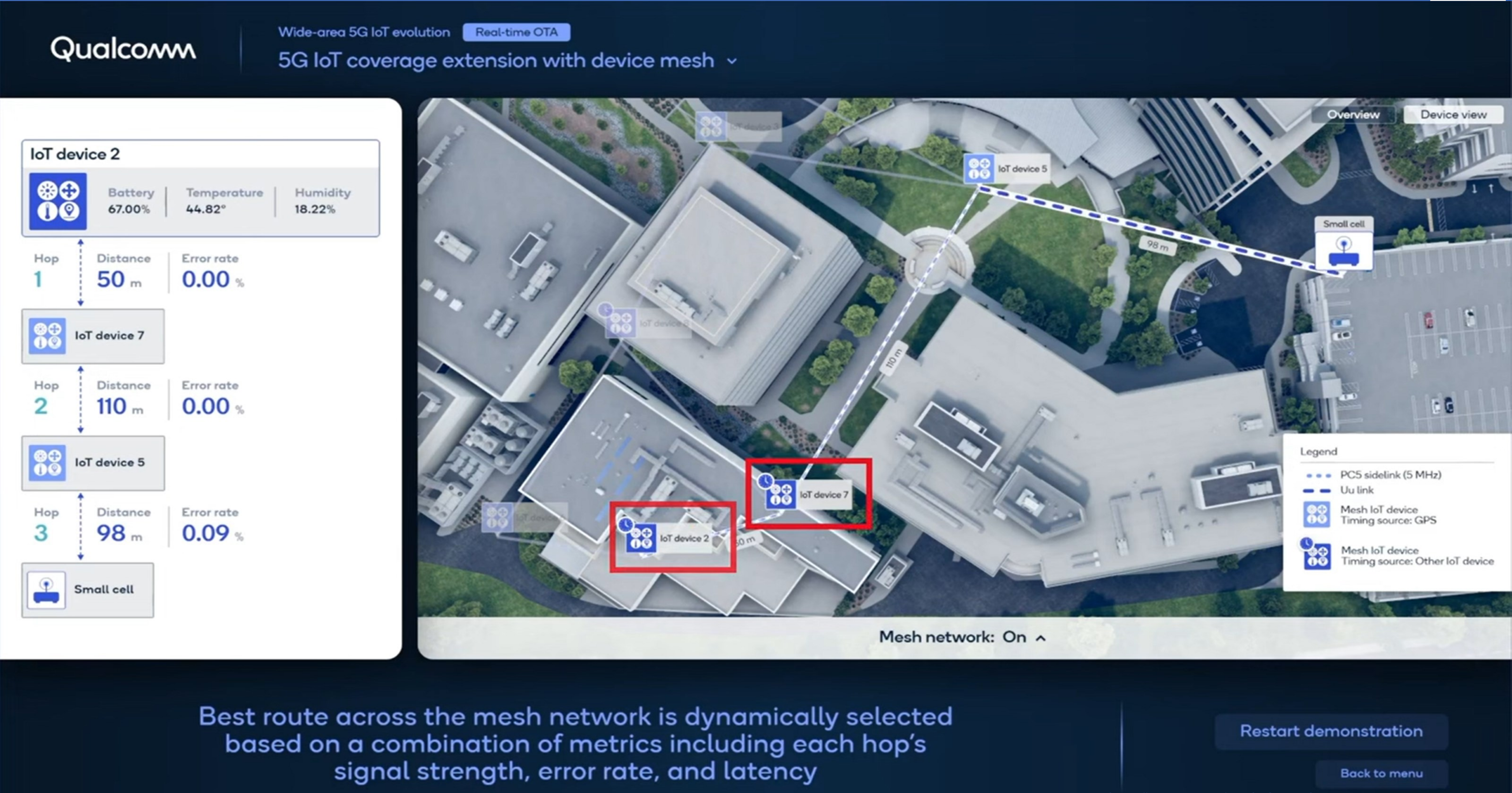
Ref.: https://www.youtube.com/watch?v=GkEth5yvQRA

Qualcomm 5G PINs Demo Presentation from MWC 2023 - 3



Ref.: https://www.youtube.com/watch?v=GkEth5yvQRA

Qualcomm 5G PINs Demo Presentation from MWC 2023 - 4



Ref.: https://www.youtube.com/watch?v=GkEth5yvQRA

3. 5GS Architecture enabling Edge Applications enhancements on Application Layer

1. 5G Architecture for enabling Cloud Applications along with the Edge Applications

The Figure illustrates the Architecture for enabling Cloud Applications along with the Edge Applications.

Cloud Application Server (**CAS**) residing outside the Edge Data Network (EDN) may need to interact with the EEL Entities e.g. for Service Continuity.

The **CAS** and **EAS** interaction is *Application Data Traffic*, which is out-of-scope of this specification.

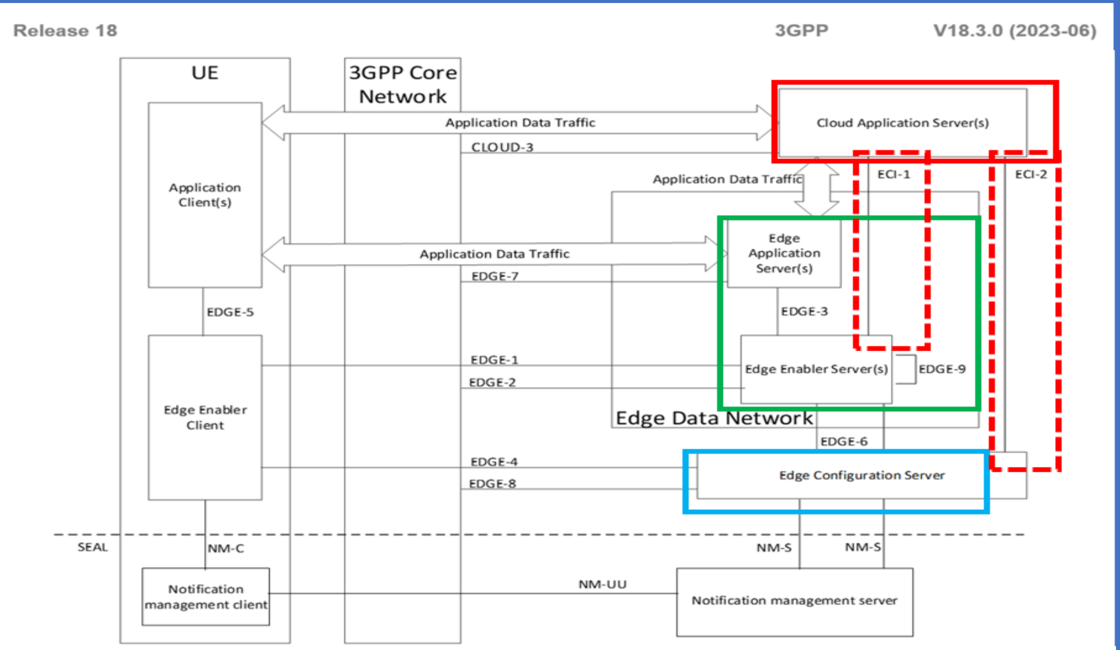


Figure: 5G Architecture for enabling Cloud Applications along with the Edge Applications with Cloud Application Server (CAS) residing outside Edge Data Network (EDN)

2. 5G Architecture for enabling Cloud Applications with Edge Applications, with CES (Cloud Enabler Server) support

The Figure illustrates the Architecture for enabling Cloud Applications along with the Edge Applications, when CES is used.

NOTE: Edge and Cloud Servers can utilize SEAL NM Service, but for simplicity such an interaction is not depicted in the figure.

Cloud Application Server (**CAS**) residing in the ***Cloud DN*** may need to interact with the *Cloud Enabler Server* (**CES**) which is part of the EEL for interworking, e.g. for **Service Continuity**.

The CAS and EAS interaction is Application Data Traffic, which is out-of-scope of this specification

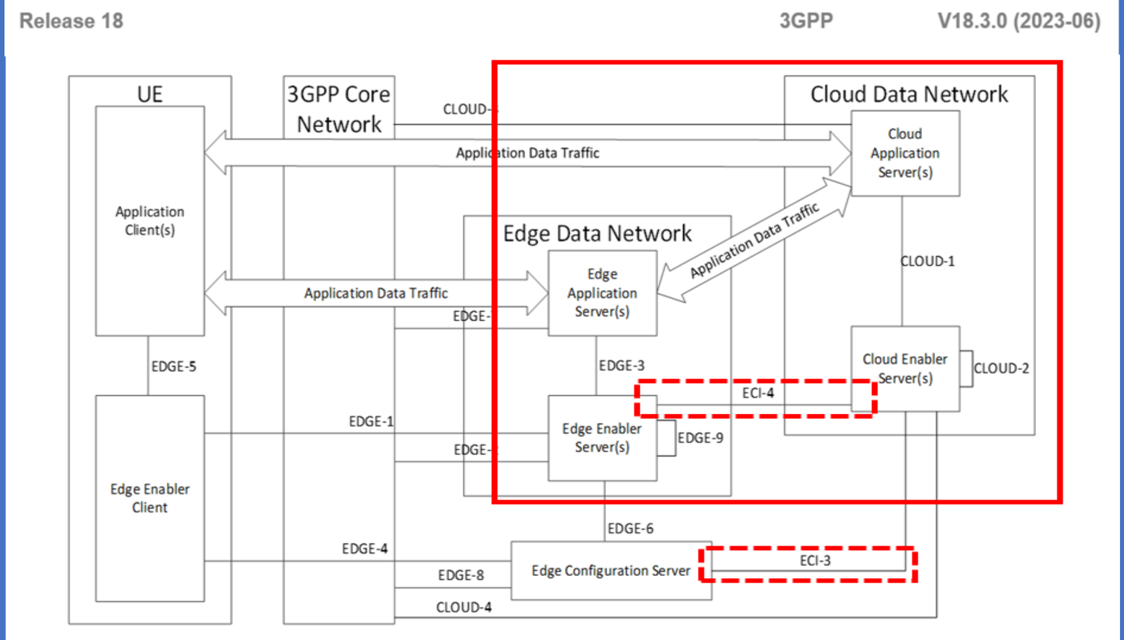


Figure: 5G Architecture for enabling Cloud Applications along with the Edge Applications with Cloud Enabler Server (CES) residing on the CDN

3. 5GS Architecture enabling Edge Applications enhancements on Application Layer

Edge-Cloud Application Servers KPI Service enablement Data Rendering Requirements **for High Data Rate and Low Latency Services**

e.g. ***Use Case Augmented/Virtual Reality* (UC AR/VR)**

The 5G System shall support **Service Continuity for AR/VR** to support "Immersive" User Experience under high UE Mobility.

When it comes to implementation of Applications containing AR/VR components, the Requirements on the 5G Network could depend on Architectural choices implementing these Services.

Note 3 in the Table, there is an example on such dependencies for a VR Application in a 5G System. The Table illustrates additional Use Cases and provides more corresponding requirements on the 5G System.

- Cloud/Edge/Split Rendering: Cloud/Edge/Split Rendering is characterized by the transition and exchange of the Rendering Data between the Rendering Server and Device.

- Gaming or Training Data Exchanging: The UC is characterized by the exchange of the Gaming or Training Service Data between two (2) 5G connected AR/VR Devices.

- Consume VR Content via tethered VR headset: This UC involves a tethered VR Headset receiving VR Content via a connected UE; this approach alleviates some of the computation complexity required at the VR Headset, by allowing some or all decoding functionality to run locally at the connected UE. The requirements in the table refer to the "direct" wireless link between the tethered VR Headset and the corresponding connected UE.

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Table KPI Table for additional high data rate and low latency service

Use Cases	Characteristic parameter (KPI)			Influence quantity		
	Max allowed end-to-end latency	Service bit rate: user-experienced data rate	Reliability	# of UEs	UE Speed	Service Area (note 2)
Cloud/Edge/Split Rendering (note 1)	5 ms (i.e. UL+DL between UE and the interface to data network) (note 4)	0,1 to [1] Gbit/s supporting visual content (e.g. VR based or high definition video) with 4K, 8K resolution and up to120 frames per second content.	99,99 % in uplink and 99,9 % in downlink (note 4)	-	Stationary or Pedestrian	Countrywide
Gaming or Interactive Data Exchanging (note 3)	10ms (note 4)	0,1 to [1] Gbit/s supporting visual content (e.g. VR based or high definition video) with 4K, 8K resolution and up to120 frames per second content.	99,99 % (note 4)	≤ [10]	Stationary or Pedestrian	20 m x 10 m; in one vehicle (up to 120 km/h) and in one train (up to 500 km/h)
Consumption of VR content via tethered VR headset (note 6)	[5 to 10] ms (note 5)	0,1 to [10] Gbit/s (note 5)	[99,99 %]	-	Stationary or Pedestrian	–

NOTE 1: Unless otherwise specified, all communication via wireless link is between UEs and network node (UE to network node and/or network node to UE) rather than direct wireless links (UE to UE).
NOTE 2: Length x width (x height).
NOTE 3: Communication includes direct wireless links (UE to UE).
NOTE 4: Latency and reliability KPIs can vary based on specific use case/architecture, e.g. for cloud/edge/split rendering, and can be represented by a range of values.
NOTE 5: The decoding capability in the VR headset and the encoding/decoding complexity/time of the stream will set the required bit rate and latency over the direct wireless link between the tethered VR headset and its connected UE, bit rate from 100 Mbit/s to [10] Gbit/s and latency from 5 ms to 10 ms.
NOTE 6: The performance requirement is valid for the direct wireless link between the tethered VR headset and its connected UE.

5G Architecture for Hybrid and Multi-Cloud Environments

The Main Challenges to overcome in a Hybrid & Multi-Cloud Strategy are:

1. Maintaining Portability; 2. Controlling the Total Cost of Ownership (TCO); 3. Optimizing Productivity & Time to Market (TTM).

DevOps – *a Set of Practices* that brings together *SW Development & IT operations* with the Goal of Shortening the Development & Delivery Cycle & increasing SW Quality **- is** often thought of and discussed **in the Context of a Single Company or Organization. The Company usually Develops the SW, Operates it & Provides it as a Service to Customers,** according to the **SW-as-a-Service (SaaS) Model. Within this context**, it is easier to have **Full Control over the Entire Flow**, including **Full Knowledge of the Target Deployment Environment.**

In the **Telecom Space**, by contrast, we typically follow the **"as-a-Product (aaP) Business model**, in which **SW is developed by Network SW Vendors** e.g. as Ericsson (Nokia, Huawei, ZTE) & provided to Communication Service Providers (CSPs) that Deploy & Operate it within their Network. This **Business Model requires the consideration of additional aspects**.

The most important contrasts between the Standard DevOps SaaS Model & the Telecom aaP Model are the **Multiplicity of Deployment Environments & the fact the Network SW Vendor Development Teams cannot know upfront exactly what the Target Environment looks like**. Although a SaaS Company is likely to Deploy & Manage its SW on two (2) or more different Cloud Environments, **this is inevitable within Telco**, as each CSP creates &/or selects its own Cloud infrastructure (Fig. 1 below).

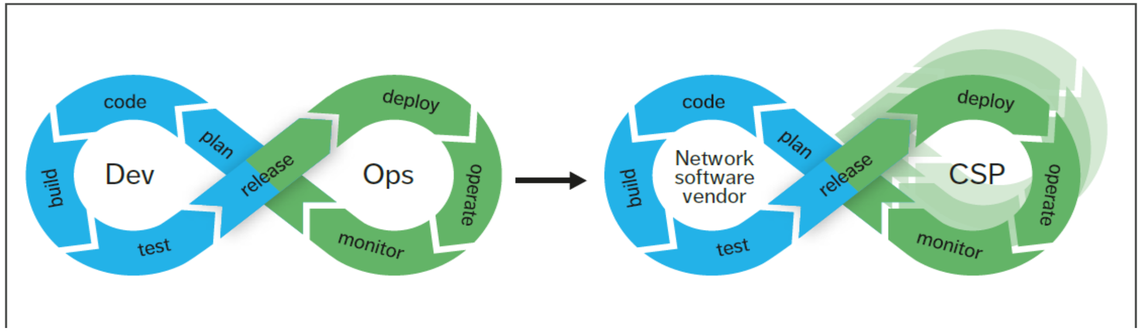

Figure 1: The DevOps and (Telecom) aaP Business Models

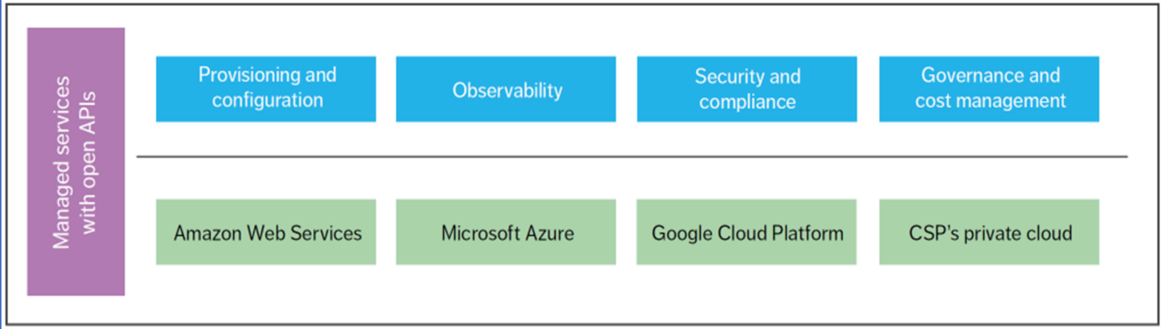

Figure 3: Key Enablers for a Multi-Cloud Native Application

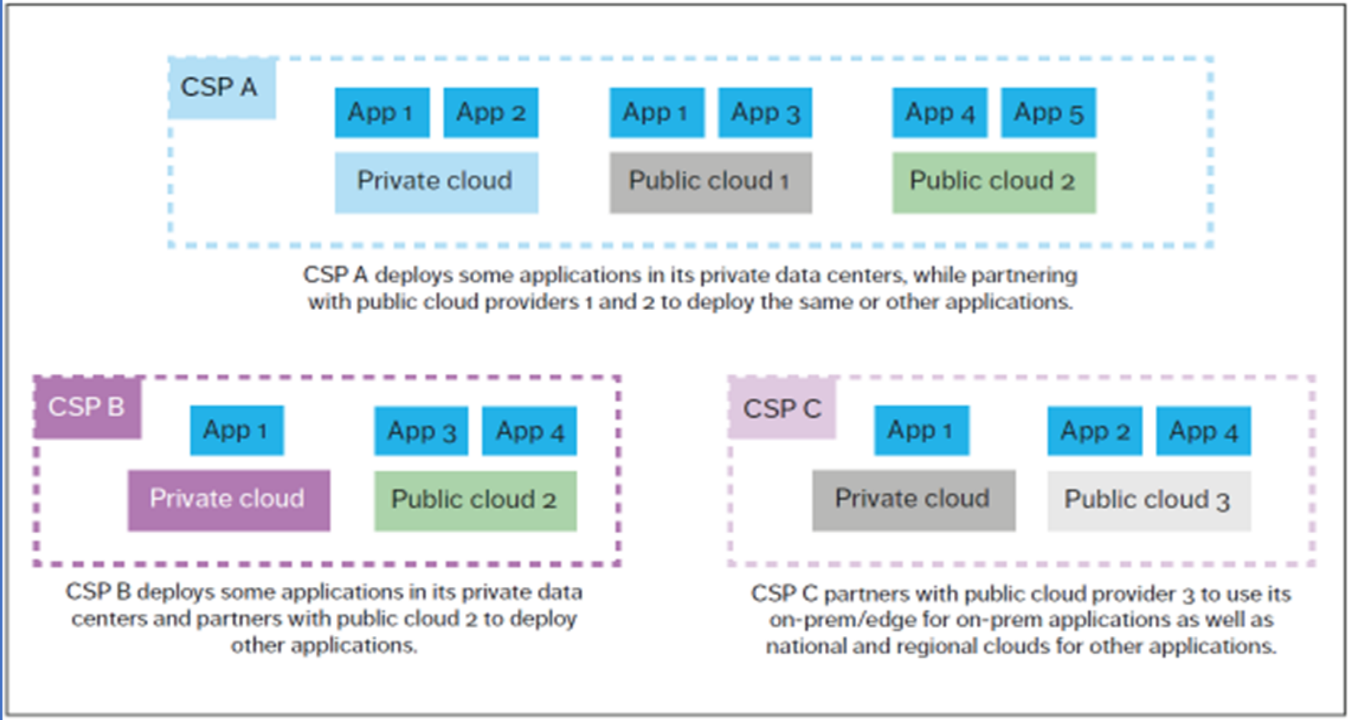

Figure 2: Examples of Hybrid and Multi-Cloud Deployment Scenarios that Applications must be able to support

Remarks & Questions?