5G Advanced and B5G (Beyond 5G) Networks

5G Personal IoT Networks (PINs)
with selected "5G Advanced" System selected Feature Capabilities

to
LF Edge Akraiio TSC

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Table of Contents (ToC)

I. Commercial Aspects
   I.1. 5G SA (SBA) "difference" from 2G, 3G, 4G/LTE, 5G NSA Capabilities
   I.3. G.A.I.N. Model (What the Customer "N"eeds to resolve their "I"ssues, in order to be able to "A"chieve their "G"oals) with GIFBP Matrix for Customer KIA
   I.4. 3G Platforms enabling Data generating Service Applications as "legacy" Solutions towards 5G Advanced evolvement of AEF (Application Enablement Frameworks)

II. 5G Advanced PINs (Personal IoT Networks)
   II.1. 5G IoT evolvement from CPNs (Customer Premises Networks with MA-RAT) to PINs (Personal IoT Networks).
   II.2. 5G Advanced PINs enhancements on Network Layer
   II.3. 5G Advanced PINs enhancements on Application Layer
   II.4. 5G Advanced Application Layer enablement evolvement through IoT - PCS (Platform Common Services) for VAL (Vertical Application Layer)
   II.5. 5G Advanced enhanced Application Data Analytics & Enablement (may be with some added info from Network Data Reporting & Analytics Architecture & Model)
   II.6. 5G Advanced Messaging Architecture for mIoT UCs

III. Practical examples of PINs deployment (high level) in selected Smart M2M SAREFs (Smart Applications REFerence Ontology) specified 10 UCs as e. g.
   III.1. 1 Smart Building - use of "Temperature" (not from "Application", but from "End-user" point of view)
   III.2. Wearables - not the "classical"/"traditional" Applications point of view, satisfying "a need", but from End-user perspective providing "progress within "functional, social & emotional context" to End-Users (as e.g. with the integration with "Smart Building" & "Smart City" UCs).
   III.3. Example of Selected 5G Advanced Features/Functionalties for specific, Key Issues - oriented Solutions
      - 5G Advanced evolvement for End-user APIs enabling obtaining/revoking "consent" and "Authorization" Function
      - selected features from Network and Application Layer enhancements on Architecture for enabling Applications on the "Edge" (e.g. EAS/CAS connectivity with 5G specified Data Split Rendering QoS Service Requirement)
      - 5G Advanced "PINs" in 5G Advanced "equivalent NPNs/SNPNs and 5G Advanced LAN-VNs with Generic Management Exposure & Communication Capability for Service Id Grouping & UPF selection/re-selection for grouping of Services and Users, 5G Advanced CN & Radio Capabilities Optimization configurations & UPF-UE Performance Management Communication Function for enabling Service QoS Requirements (5QI), Enhancements for FoF (Factory of the Future), URLLC (Ultra Reliable Low Latency Communication & IloT), MBS (Multicast broadcast Services), Specified Architecture of Messaging for mIoT UCs handling "legacy Messaging" & connection to both PINs & 5G Advanced Architecture for ProSe ("Proximity Services") for "direct Communication".

IV. 5G Advanced evolvement towards B5G/6G
   IV.1 Will there be "6G" and/or if the same "G" Framework (applied to 2G, 3G, 4G, 5G) also is "applicable" for/after 5G Advanced/B5G Systems/Networks? Since
   IV.2. 3GPP 5G Advanced as a focal point for integrating three (3) SDOs - Standard Development Organizations) Architecture Specifications as part of the evolvement towards RAW (Reliable & Available Wireless) enabling 5G Advanced Capabilities for "System selected KIs (Key Issues) configuration" of Networks characterized as "Programmable", "Predictable", "Deterministic" Network(s) enabling "User & (Service) Performance Guarantees".
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.

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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<tr>
<th>50 SA/SBA (5GC and NG-RAN) QoS 5QI (5G QoS Identifier)</th>
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**Notes:**
1. A packet which is delayed more than PGII is not counted as lost, thus not included in the PGII.
2. It is required that Default MME is supported by a 5G system supporting the related 5QIs.
3. The maximum Transfer Unit (MTU) size considerations in clause 9.3 and Clause 7 of TS 23.001 [64] are also applicable. IP fragmentation may have impacts to CN/PDN and details are provided in clause 5.6.10.
4. A static value for the CN PDUs of 128 bytes to the delay between a UPR terminating MG and a PGW should be subtracted from a given QoS to derive the packet delay budget that applies to the radio interface. For a dynamic PGW case, see clause 5.7.3.4.
5. A static value for the CN PDUs of 32 bytes to the delay between a UPR terminating MG and a PGW should be subtracted from a given QoS to derive the packet delay budget that applies to the radio interface. For a dynamic PGW case, see clause 5.7.3.4.
6. A static value for the CN PDUs of 32 bytes to the delay between a UPR terminating MG and a PGW should be subtracted from a given QoS to derive the packet delay budget that applies to the radio interface. For a dynamic PGW case, see clause 5.7.3.4.
7. For mission Critical services, if it may be assured that the UPR terminating MG is located "close" in the 5QI (roughly 10 ms) and is not normally used in a long distance, home routing enabling situation, remove a static value for the CN PDUs of 10 ms for the delay between a UPR terminating MG and a PGW, which should be subtracted from the PGII to derive the packet delay budget that applies to the radio interface.
8. In both RRC idle and RRC Connected mode, the PGII requirement for these 5QIs can be relaxed (but not to a value greater than 125 ms for the first packet). In a downlink data or signalling burst in order to permit reasonable battery saving (CRK) techniques.
9. It is expected that RQoE and SA-49 are used together as follows: Mission Critical Traffic to Task Group in QoS 5 is not used for signaling. It is expected that the amount of traffic per BS will be similar or less compared to the MRQI signaling.
10. In both RRC idle and RRC Connected mode, the PGII requirement for these 5QIs can be relaxed for the first packet(s) in a downlink data or signaling burst in order to permit battery saving (CRK) techniques.
11. In RRC idle mode, the PGII requirement for these 5QIs can be relaxed for the first packet(s) in a downlink data or signaling burst in order to permit battery saving (CRK) techniques.
12. This 5QI value can only be assigned over segmenting the smaller radio bearer. The UE and any application running on the UE, is not allowed to bypass this 5QI value.
13. A static value for the CN PDUs of 20 ms for the delay between a UPR terminating MG and a PGW should be subtracted from a given QoS to derive the packet delay budget that applies to the radio interface.
14. This 5QI is not supported in the Release of the specification on the only so far used for transmission of V2X messages over related services as defined in TS 23.208 [7] but is the value recommended for future use.
15. For "live" uplink streaming (see TS 26.291 [3]), guidelines for PGII values of the different 5QIs compared to the latency configurations defined in TR 26.950 [7] (in order to support higher latency related streaming services above 5QI 5), if different 5QIs and PGII combinations are needed these combinations will have to use non-standard 5QIs.
16. These services are expected to need much larger 5QI values to be signaled to the UE. Support for such larger 5QI values with low latency and high reliability is likely to require a suitable RAN configuration, for which the simulation scenarios in TR 38.922 [7] would contain some guidance.
17. The worst case one way propagation delay for GEO satellites is expected to be 2 - 70ms. A 20ms 1G radio link, and 15 ms to LEO at 600ms. The UE scheduling delay that needs to be added is typically 1 Rice - 5 ms (as defined for the GEO - Core for LEO at 600ms. Based on that, the 5QI 5 Packet delay budget is not applicable for 5QIs that require SA-49 PGII budget - the sum of these values when the specific values of packet access are used) . QoS 5 can accommodate the worst case 5QI for GEO satellite type.

**Note:** It is preferred that a value less than 64 is allocated for any new standardized 5QI of non-GBR resource type. This is to allow for option 1 to be used as described in clause 5.7.1.13 (as the QoS 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 12) | Packet Error Loss Rate (NOTE 5) | Maximum Burst Volume (NOTE 8) | Data Rate Averaging Window | Example Services
--- | --- | --- | --- | --- | --- | --- | ---
1 | (NOTE 3) | 2 | 100 ms (NOTE 11) | 10^{-2} | 0.5 | 60 ms (NOTE 8) | Conversational Voice
2 | (NOTE 3) | 2 | 150 ms (NOTE 11) | 10^{-3} | 0.5 | 200 ms (NOTE 8) | Conversational Video (Live Streaming)
3 | (NOTE 3, NOTE 14) | 3 | 50 ms (NOTE 11) | 10^{-3} | 0.5 | 50 ms (NOTE 8) | Real-Time Gaming, V2X messages
4 | (NOTE 3) | 5 | 300 ms (NOTE 11) | 10^{-6} | 0.8 | 300 ms (NOTE 8) | Non-Comversational Video (Buffered Streaming)
5 | 0.7 | 75 ms (NOTE 11) | 10^{-2} | Mission Critical User plane Push To Talk voice (e.g., MCPTT)
6 | (NOTE 3) | 2 | 100 ms (NOTE 8) | 10^{-2} | Mission Critical User plane Push To Talk voice
7 | 1.5 | 100 ms (NOTE 11) | 10^{-3} | Mission Critical Video user plane
8 | 2.5 | 50 ms (NOTE 11) | 10^{-2} | V2X messages
9 | 5.6 | 150 ms (NOTE 11) | 10^{-6} | "Live" Uplink Streaming
10 | 3.6 | 300 ms (NOTE 11) | 10^{-4} | "Live" Uplink Streaming
11 | 6.5 | 500 ms (NOTE 11) | 10^{-4} | "Live" Uplink Streaming
12 | 7.6 | 500 ms (NOTE 11) | 10^{-4} | "Live" Uplink Streaming
13 | 1 | 100 ms (NOTE 11) | 10^{-10} | IMS Signalling
14 | 3 | 300 ms (NOTE 11) | 10^{-3} | Video (Buffered Streaming) e.g., e-mail, e-mail, chat, etc.
15 | (NOTE 3) | 7 | 100 ms (NOTE 11) | 10^{-4} | Voice, Video (Live Streaming), Interactive Gaming
16 | 8 | 300 ms (NOTE 11) | 10^{-3} | Video streaming e.g., www, video, video, etc.
17 | 9 | 300 ms (NOTE 11) | 10^{-3} | TCP-based e.g., www, e-mail, chat, etc.
18 | 6 | 300 ms (NOTE 11) | 10^{-3} | Voice, Video (Live Streaming), Interactive Gaming
19 | 0.5 | 10 ms (NOTE 8) | 10^{-6} | Mission Critical delay sensitive signalling (e.g., MC-PDTC signalling, MC Video signalling)
20 | 0.5 | 20 ms (NOTE 8) | 10^{-6} | Mission Critical Data (e.g., example services are the same as QCI 6/8/9)
21 | 0.5 | 50 ms (NOTE 8) | 10^{-6} | V2X messages
22 | 0.5 | 80 ms (NOTE 8) | 10^{-6} | Low latency multimedia applications (TCP/UDP-based)

NOTE 1: A delay of 20 ms for the delay between a PCRF and a radio base station should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface. The average delay is the average of the case where the PCRF is located "far" from the radio base station, e.g., with the radio base station serving the radio access network (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. If 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. Note that the PDB defines an upper bound. Actual packet delays - in particular for GBR traffic - should typically be less than the PDB for all QCI as long as the UE has enough radio resources specified for that QCI.

NOTE 2: The rate of non-compliances related to packet losses that may occur between a radio base station and a PCRF should be regarded as negligible. A VPLR value specified for a standardised 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/bearer is uplink driven, where packet filtering 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.

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. mostly 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 or subscriber group. Also in this case, the SDF aggregate/bearer is uplink driven, where packet filtering 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 "prefered bearer" for "premium subscribers".

NOTE 6: This QCI is typically used for the default bearer of a UEPDN for non-precivilized subscribers. Note that AMBR can be used as a "tool" to provide subciber differentiation between subscribers 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 PCRF is located "close" to the radio base station (roughly 10 ms) and is not normally used in a long distance, high speed roaming situation. Hence delay of 20 ms for the delay between a PCRF 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 QCI can be relaxed (but not to a value below that of the first PDB for the first PDB). In downlink data or signalling burst in order to permit reasonable battery saving (EDRX) techniques.

NOTE 9: If it is expected that QCI 65 and QCI 69 are used together to provide Mission Critical Push to Talk service (e.g., QCIs are not 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: The PDB requirement for these QCI can be relaxed for the first PDB in a downlink burst if battery saving (EDRX) techniques.

NOTE 11: In RRC Idle mode, the PDB requirement for these QCI can be relaxed for the first PDB in a downlink burst if battery saving (EDRX) 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 with E-UTRAN.

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

NOTE 15: A delay of 20 ms for the delay between a PCRF 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: The "live" uplink streaming refers to cases where values of the different QCI correspond to the latency requirements defined in

NOTE 17: In support of higher latency reliable streaming services (above 500ms RPD), different PDB and PELR combinations are needed for these cases. These will have to use non-standardized QCI.

NOTE 18: The PDB applies to bursts that are not greater than Maximum Burst Volume.

NOTE 19: 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 Volume and GBR requirements but which are not delivered within the Packet Delay Budget.

NOTE 20: 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 21: A delay of 10 ms for the delay between a PCRF 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 22: This Maximum Data Burst Volume 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 Annex C and further reduced by 4 bytes to allow for the usage of a GTP-U extension header).

NOTE 23: This QCI is typically associated with a Dedicated EPS bearer.

NOTE 24: A delay of 5 ms for the delay between a PCRF and a radio base station should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface.
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.

**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 (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

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.
5G System (5GS) Architectural Enhancements for PINS - Network Layer

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.

<table>
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<tr>
<th>Key Issue</th>
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<td>Authorization for PIN</td>
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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)."
**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

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**Mapping of solutions to key issues**

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**PIN Profile in a PIN**

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<th>Parameter Description</th>
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<th>PEMC</th>
<th>PEGC</th>
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<td>The identifier of the PIN</td>
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<tr>
<td>PIN Description</td>
<td>Human-readable description of the PIN, for example, the company name, location or the type of service.</td>
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<tr>
<td>Duration</td>
<td>Specifies the time period of how long the PIN can be active</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Maximum number of PIN elements</td>
<td>Maximum number of PIN elements allowed to pin the PIN</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>PIN service</td>
<td>List of service that a PIN can provide, including the PINE service or the service that can be performed by an application client on PIN: PIN service Provider Identifier &gt; PIN service type &gt; PIN service Feature</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>PEMC list</td>
<td>The list of identifiers of the PIN elements which can be allowed to take the role as PEMC (e.g.: PIN client ID, UE GPR etc.) and also it contains whether the role is primary or secondary</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>PEGC ID list</td>
<td>The list of identifiers of the PIN elements which can be allowed to take the role as PEGC (e.g.: PIN client ID, UE GPR etc.)</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>PIN server ID</td>
<td>The identifier of the PIN server that serves the PIN</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>PIN server/endpoint</td>
<td>Endpoint information (e.g., URI, FG2DN, IP address) used to communicate with the PIN server</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>PIN Elements List</td>
<td>List of PIN elements which can be allowed to join the PIN &gt; PIN element ID</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

**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...
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.
The UE Data Exposure Client (DEC) is responsible for sending Data request to the Data Information AF (IEAF, evolved REL. 17 DCA/F/AF).

Distributed/Federated Learning (FL) over SGS (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 SGS 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 5GN, 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. Analytics 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 Requirement & Operational behaviours are organized into various Application AI/ML Assistance (AaaML) Service Profiles where Each Profile defines specific AaaML Services. The AaaML Services are a Set of Collective Extensions to the existing SGS Services & the new SGS 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).
A Current Smart Home IoT Deployment example

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.

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

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.

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.

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

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

Figure: 5GS PIN Personal IoT Network Reference Architecture

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

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
With mesh networking, out-of-coverage outdoor and indoor devices can be connected with routing and timing support (i.e., no need for GPS).
Best route across the mesh network is dynamically selected based on a combination of metrics including each hop’s signal strength, error rate, and latency.
Best route across the mesh network is dynamically selected based on a combination of metrics including each hop’s signal strength, error rate, and latency.
Best route across the mesh network is dynamically selected based on a combination of metrics including each hop's signal strength, error rate, and latency.
3. 5G 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.

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.
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.

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

<table>
<thead>
<tr>
<th>Use Cases</th>
<th>Characteristic parameter (KPI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max allowed end-to-end latency</td>
</tr>
<tr>
<td>Cloud/Edge/Split Rendering</td>
<td>5 ms (i.e. 16 kbps between UE and (note 4)</td>
</tr>
<tr>
<td>Gaming or Interactive Data Exchanging (note 3)</td>
<td>10 ms (note 4)</td>
</tr>
<tr>
<td>Consumption of VR content via tethered VR headset (note 6)</td>
<td>[5 to 10] ms (note 6)</td>
</tr>
</tbody>
</table>

**NOTES:**
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).
2. Length x width x height.
3. Communication includes direct wireless links (UE to UE).
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.
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 Mbits to [10] Gbits and latency from 5 ms to 10 ms.
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](image1)

![Figure 2: Examples of Hybrid and Multi-Cloud Deployment Scenarios that Applications must be able to support](image2)