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Permissioned Distributed Ledgers (PDL); Architecture enhancements for PDL service provisioning in telecom networks

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Reference

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Foreword

This Group Specification (GS) has been produced by ETSI Industry Specification Group (ISG) Permissioned Distributed Ledger (PDL).

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Executive summary

The present document outlines the architecture enhancements for Permissioned Distributed Ledger (PDL) service provisioning in telecom networks. The present document, produced by the ETSI Industry Specification Group (ISG) for Permissioned Distributed Ledger (PDL), aims to specify the technical solutions necessary for enabling telecom networks to provision various PDL services over their infrastructure. Key aspects of the present document include:

- **PDL Service Provisioning Architecture Model**: The architecture model is designed to accommodate and operate PDL services in next-generation telecom networks, taking into account the constraints of Public Land Mobile Networks (PLMNs) such as geographically segmented network domains and heterogeneous resource capacities.

- **PDL Functions**: The architecture consists of several PDL functions, including the Distributed Ledger Anchor Function (DLAF), Distributed Ledger Repository Function (DLRF), Distributed Ledger Enabler (DLE), Distributed Ledger Data Storage Management (DLDSM), and Distributed Ledger Governance Function (DLGF).

- **High-Level Features**: The present document specifies high-level functionalities and features of the PDL provisioning architecture, including PDL service management, onboarding, connectivity management, security aspects, performance assurance, and information exposure.
- **Procedures for PDL Service Provisioning**: Detailed procedures are provided for PDL service provisioning, including service description, DLE instantiation, service deployment, onboarding, update, termination, and redaction capability provisioning.
- **Integration with Telecom Networks**: The present document discusses various integration options for PDL capabilities with telecom networks, including telecom-native and telecom-connected PDL capabilities, and deployment considerations for PDL functions.
- **Recommendations**: The present document concludes with recommendations for further study on integrating the proposed PDL service provisioning architecture with telecom network architecture to provide PDL-enhanced telecom network services, focusing on signalling protocol design, integration of PDL service procedures with telecom network service procedures, and integration of PDL service signalling with telecom network service protocols.

Introduction

The present document outlines the architecture enhancements for Permissioned Distributed Ledger (PDL) service provisioning in telecom networks. Produced by the ETSI Industry Specification Group (ISG) for Permissioned Distributed Ledger (PDL), the present document aims to specify the technical solutions necessary for enabling telecom networks to provision various PDL services over their infrastructure. The integration of PDL capabilities into telecom networks is driven by the need for secure, reliable, and scalable distributed ledger services that can support a wide range of applications, from basic mobile internet connectivity to compute-oriented tasks for both mobile users and Over-The-Top (OTT) service providers. The proposed enhancements focus on extending the architectural and signalling aspects of telecom networks to integrate distributed ledger capabilities as part of their native features. The present document covers the architecture model for PDL service provisioning, high-level features of the system, detailed descriptions of PDL functions, and procedures for PDL service provisioning. It also discusses various integration options for PDL capabilities with telecom networks, including telecom-native and telecom-connected PDL capabilities, and provides recommendations for further study on integrating the proposed PDL service provisioning architecture with telecom network architecture to provide PDL-enhanced telecom network services.

1 Scope

The present document will specify technical solutions for enabling a telecom network to be capable of provisioning various PDL services over the infrastructure itself. The scope of the present document aims to specify required end-to-end enhancements/modifications on:

1) The telecom network architecture across user entities, (radio) access network, core network and service providers (e.g. by adding new functions or enhancing functions);
2) Functionalities of the new functions and/or enhanced functions; and
3) Interfaces and procedures among the new functions and/or existing functions.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are necessary for the application of the present document.

[1] ETSI GS PDL 012 (V1.1.1): "Permissioned Distributed Ledger (PDL); Reference Architecture".

[2] ETSI GS PDL 023 (V1.1.1): "PDL service enablers for Decentralized Identification and Trust Management".

2.2 Informative references

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] "Merkle-tree" from Wikipedia® in English, 10 September 2024. Page Version ID: 1245066542.

[i.2] "Trie" from Wikipedia® in English, 02 September 2024. Page Version ID: 1243621934.

[i.3] 3GPP TS 23.501 (V19.0.0): "3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; System architecture for the 5G System (5GS); Stage 2 (Release 19)".

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

3GPP	3rd Generation Partnership Project
AF	Application Function
AMF	Access and Mobility Function
AUSF	Authentication Server Function
CMP	Certificate Management Protocol
DAPP	Decentralized APPlication
DLAF	Distributed Ledger Anchor Function
DLDSM	Distributed Ledger Data Storage Management
DLE	Distributed Ledger Enabler
DLGF	Distributed Ledger Governance Function
DLRF	Distributed Ledger Repository Function
DN	Data Network
KPI	Key Performance Indicator
LBO	Local Break Out
NEF	Network Exposure Function
NF	Network Function
OTT	Over The Top
PDU	Packet Data Unit
PLMN	Public Land Mobile Network
SBI	Service Based Interface
SEPP	Security Edge Protection Proxy
SF	Service Function
SMF	Service Management Function
TEE	Trust Execution Environment
UE	User Equipment
UPF	User Plane Function

4 PDL service provisioning architecture model

4.1 General concept

The architecture model for PDL service provisioning is to design the minimum set of PDL functions that are required to accommodate and operate a PDL service from a user in the next generation of telecom networks. A user can be either an end user like a UE or an Over-The-Top (OTT) tenant, or even the operator itself. The general concept to design the architecture model is to take into account the constraints of a PLMN such as geographically segmented network domains, distributed infrastructure elements and heterogeneous resource capacities across the entire network infrastructure. Some key concepts are to:

- Modularize the PDL function design.

- Enable each PDL function and its services to interact with other PDL functions and their services directly or indirectly via a Service Communication Proxy if required. The architecture will reuse all available intermediate functions from the underlying PLMN to route Certificate Management Protocol (CMP) messages.
- Wherever applicable, define procedures (i.e. the set of interactions between PDL functions) as services, so that their re-use is possible.
- Support capability exposure.

4.2 Architecture reference model

4.2.1 PDL Functions

The PDL service provisioning architecture consists of the following PDL functions:

- Distributed Ledger Anchor Function (DLAF).
- Distributed Ledger Repository Function (DLRF).
- Distributed Ledger Enabler (DLE).
- Distributed Ledger Enabler Service Function (DLE-SF).
- Distributed Ledger Data Storage Management (DLDSM).
- Distributed Ledger Governance Function (DLGF).

4.2.2 Single-domain reference architecture

Figure 1 depicts a single-domain PDL service system architecture, where Service-Based Interfaces (SBI) are used in the PDL service control and management plane:

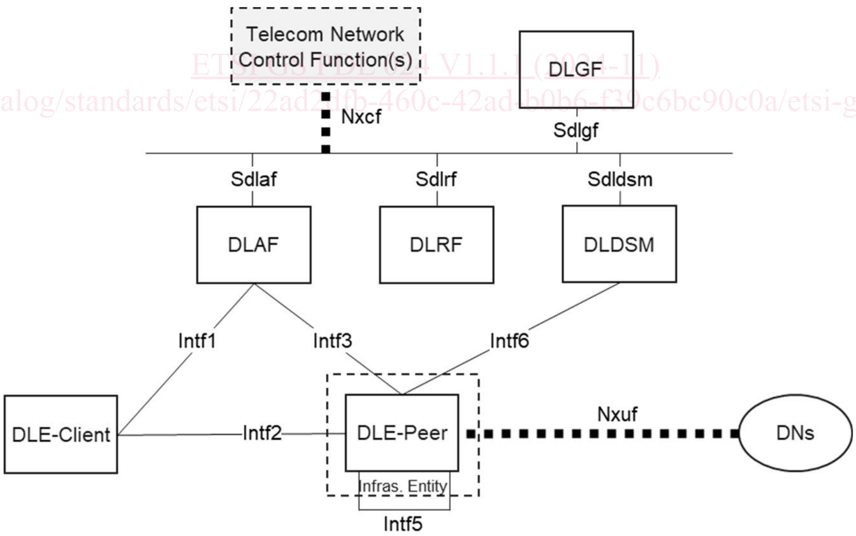


Figure 1: Single-domain PDL service architecture model with SBI in control plane

Figure 2 depicts the single-domain PDL service system architecture with reference points:

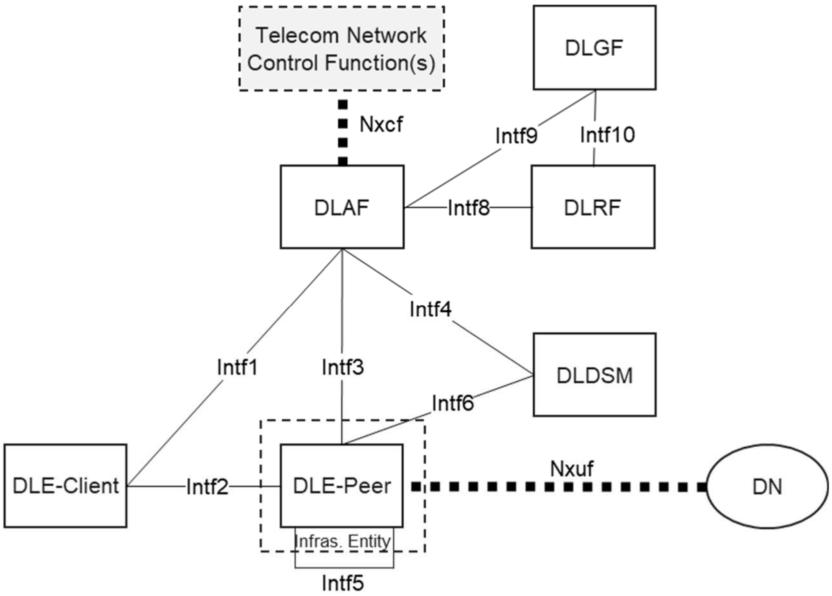


Figure 2: Single-domain PDL service architecture model with reference point representation

The architecture model represents a scenario where a DLE-Client accesses a PDL service realized by multiple DLE-Peers organized as a distributed ledger (or Blockchain) network deployed in a telecom network. The PDL service connects to a Data Network (DN). This PDL service is managed and controlled by a set of PDL functions at the upper part. In addition, the PDL functions can further interact with other telecom network control functions that are typically for existing 3GPP network services.

NOTE 1: A DLE can be a standalone function that is deployed as an individual physical or virtual function; or a DLE can be a non-standalone function that is co-located with other network functions in the telecom network infrastructure (as shown with the dash box outside). For example, a DLE can co-exist with a User Plane Function (UPF).

NOTE 2: DLDSM provides external ledger storage capacity if a DLE has limits in capacity or availability time.

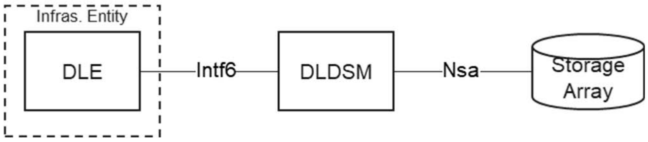
NOTE 3: Another PDL service network can be provisioned in DN. The existing PDL service running on DLEs can access to the other PDL service network via Nxuf interface. This interface can link to a UPF or a direct connection to DN. A PDL service network in DN can run the same PDL service of one consortium or a different PDL service for inter-ledger/blockchain operations. In addition, the other way to inter-work with another PDL service network is via Security Edge Protection Proxy (SEPP), instead of UPF.

NOTE 4: The PDL service architecture part may need to interact with network functions (NFs) / entities in the same telecom network for a PDL service provisioning.

NOTE 5: Nxcf interface represents the interactions between DLAF and network functions for operational purposes in the same telecom network. The interactions are done by using the services provided by both DLAF and other NFs over 3GPP SBIs.

4.2.3 Ledger data storage reference architecture

Figure 3 depicts the architecture model for external storage of the ledger data from DLE. This provides alternatives to a PDL service to offload the ledger data if there are limits on the local DLE such as short of storage or service time termination and so on.



NOTE: DLDSM only handles PDL service data instead of the operational data. When the PDL service data is offloaded from a DLE to DLDSM (and to a storage), privacy-preserving and data security policies have to be considered.

Figure 3: Architecture for external ledger data storage

4.2.4 Architecture to support PDL service information exposure

A vertical user shall be able to know the status of a PDL service that is provisioned in a telecom network. The architecture shall be able to expose the information and data of a PDL service to the end user, the tenant or both. This is related to Service Level Agreement (SLA), QoS control or relevant service intervention from an external party. Figure 4 depicts the architecture for PDL service information exposure:

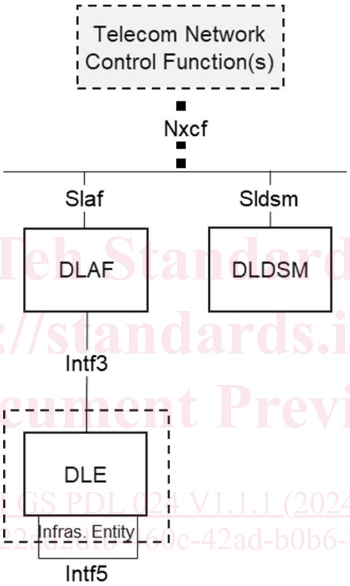


Figure 4: Architecture for PDL service information exposure

The information of a PDL service can be shared internally and externally via an SBI manner. For internal cases, operators may need the service information of the provisioned PDL service for operational purposes such as charging, QoS adaption and so on. For external cases, service providers may also need the service information to determine how to influence and/or interact with the operator for service adaptation and so on.

4.2.5 Architecture to support cross-domain PDL service deployment

Figure 5 depicts the architecture for cross-domain PDL service deployment:

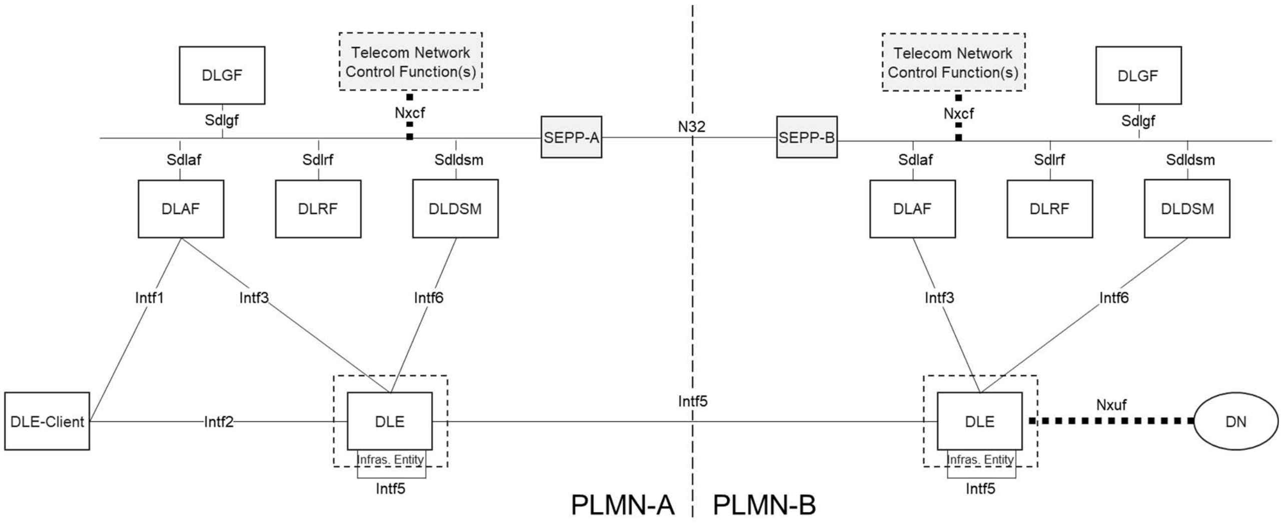


Figure 5: Architecture for cross-domain PDL service provisioning

A PDL service can be deployed across multiple PLMN domains. Different domains can refer different operational domains of one PLMN operator, or different network domains of different PLMN operators where their ownerships can be completely different.

NOTE: A PDL service provisioning is assumed that it is not done in a Local-Break-Out (LBO) mode when a DLE-Client roams in a visiting PLMN. Unlike a PDU session, a PDL service semantically involves ledger data that are stored in the PLMN(s) where it is initially provisioned. If a visiting PLMN does not participate the provisioning of that PDL service, a more efficient way is to connect the roaming DLE-Client back to its home PLMN and access the PDL service back there. Temporally extending a PDL service to a visiting PLMN requires much more efforts to build the PDL service network in the visiting PLMN part, which could trigger a lot of overheads in both PLMNs (for signalling and synchronization).

4.2.6 Service-Based Interfaces (SBIs)

The PDL service provisioning system architecture contains the following SBIs:

Sdlaf: SBI of DLAF

Sdlrf: SBI of DLRF

Sdldsm: SBI of DLDSM

Sdlgf: SBI of DLGF

4.2.7 Reference points

The PDL service provisioning system architecture contains the following reference points:

Intf1: Reference point between the PDL-Client and DLAF

Intf2: Reference point between the PDL-Client and DLE

Intf3: Reference point between the DLAF and DLE

Intf4: Reference point between the DLAF and DLDSM

Intf5: Reference point between two DLEs

Intf6: Reference point between the DLE and DLDSM

Nxuf: Reference point between the DLE and user plane connecting to DN

Intf8: Reference point between the DLAF and DLRF

Intf9: Reference point between the DLGF and DLAF

Intf10: Reference point between the DLGF and DLRF

Nxcf: A group of interfaces between the DLAF and other Telecom Network Functions

NOTE: The reference point between the DLAF and other telecom network (control) functions reuse the reference points defined in 3GPP TS 23.501 [i.3] for interacting with typical Network Functions (NFs) in a PLMN.

5 High level features of the system

5.1 General

This clause specifies the high-level functionalities and features of the PDL provisioning architecture.

5.2 PDL service management

The PDL service architecture shall support the whole lifecycle management and control of a PDL service from the time the PDL service is requested, its provisioning, deployment and operations, until its termination. In addition, the PDL service architecture shall also support the management of smart contracts intended to be deployed as an application logic of the PDL service. Specifically, PDL service management shall realize the following features:

- Handle and parse the PDL service deployment request.
- Identify network resources feasible for PDL service deployment request.
- Configure network resources with DLE capabilities (e.g. with software libraries, service policies and so on).
- Manage PDL service network topology (e.g. topological structure, links among DLEs and so on).
- Configure DLE's profile for a PDL service (e.g. consensus protocol, redaction policy and participating roles).
- Review and publish smart contracts of a PDL service (e.g. compatibility, validness and threat analysis of a smart contract), which is the responsibility of DLAF and/or DLGF.

5.3 PDL service onboarding

To leverage PDL technology for enabling future trustworthy wireless system, future wireless system needs to integrate PDL capabilities e.g. as new NFs or collocated with existing NFs in the telecom network architecture, referred to as native distributed ledger. For a DLE such as a UE as a DLE-Client to efficiently interact with such a native distributed ledger (e.g. represented by one or more DLEs), the DLE first needs to be properly onboarded to the native distributed ledger and be provisioned with necessary configuration information for interacting with it, referred to as DLE onboarding to native wireless PDL or PDL service onboarding.

PDL service onboarding shall realize the following features:

- Select DLEs that need to be onboarded to a native distributed ledger.
- Determine PDL service address (e.g. a blockchain address) generation scheme for each selected DLE.
- Determine DLAF for each selected DLE.
- Notify the determined PDL service address generation scheme and the determined DLAF to each selected DLE.
- Authenticate the PDL service address of each selected DLE.