# ETSI TS 128 314 V18.0.0 (2024-05)


**5G;**
**Management and orchestration;**
**Plug and Connect;**
**Concepts and requirements**
**(3GPP TS 28.314 version 18.0.0 Release 18)**

Reference
RTS/TSGS-0528314vi00

Keywords
5G

***ETSI***

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# Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

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y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

In the present document, modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

# Introduction

The present document is part of a TS family covering the 3rd Generation Partnership Project Technical Specification Group Services and System Aspects, Management and orchestration; as identified below:

**TS 28.314: "Plug and Connect; Concepts and requirements".**

TS 28.315: "Plug and Connect; Procedure flows".

TS 28.316: "Plug and Connect; Data formats".

# 1 Scope

The present document specifies concepts, use cases and requirements for *Plug and Connect* NE in 3GPP systems.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 33.310: "Network Domain Security (NDS); Authentication Framework (AF)".

[3] IETF RFC 4210: "Internet X.509 Public Key Infrastructure Certificate Management Protocol".

[4] IETF RFC 4211: "Internet X.509 Public Key Infrastructure Certificate Request Message Format (CRMF)".

# 3 Definitions of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

**Plug and Connect:** The procedure by which a NE gets basic connectivity information after it is powered up and gets connected to its management system.

**Software and Configuration Server (SCS):** A server that provides software and configuration functions for each connected network element.

## 3.2 Symbols

Void.

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

| | |
|---|---|
| CA | Certification Authority |
| CMP | Certificate Management Protocol |
| DHCP | Dynamic Host Configuration Protocol |
| DNS | Domain Name System |
| FQDN | Fully Qualified Domain Name |
| NAT | Network Address Translation |

| | |
|---|---|
| NE | Network Element |
| PnC | Plug and Connect |
| RA | Registration Authority |
| SCS | Software and Configuration Server |
| SeGW | Security Gateway |
| VLAN | Virtual LAN |

# 4 Concepts and background

## 4.1 Plug and Connect Concept

### 4.1.1 General description

Plug and connect is a list of procedures for connecting the NE to its management system. The basic steps of Plug and Connect are described in clause 6.1.1.

The entities involved in the PnC concept are NE, DHCP server, DNS Server, Certification Authority server, SCS (including the Initial and Serving SCS that could be the same in certain deployment scenarios), Security Gateway.

### 4.1.2 Network Scenarios

#### 4.1.2.1 NE connected via a Non-Secure, Operator Controlled Network

An NE is typically connected to the operator's network according to one of the following scenarios:

In Figure 4.1.2.1.1, the NE is connected directly to a network controlled by the operator. The NE can use IP Infrastructure services (DHCP Server, DNS Server, etc.) in the Non-secure Operator Network. The Operator has full control of these nodes. One or more Security Gateways protect the Secure Operator Network from malicious NEs. Within the Secure Operator Network, there are also IP Infrastructure nodes.

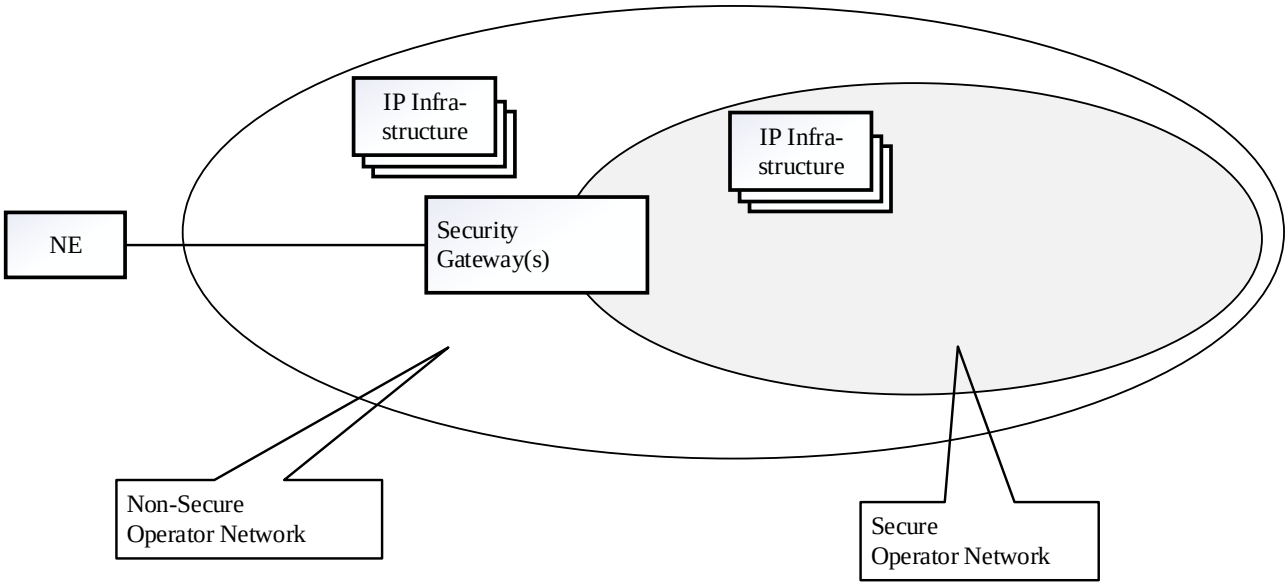


**Figure 4.1.2.1.1: NE connected to a Non-Secure Operator Network**

#### 4.1.2.2 NE connected via an External Network

In Figure 4.1.2.2.1, the NE is connected to a network controlled by an entity external to the Operator. In contrast to the first scenario, the IP Infrastructure nodes in the External Network are not fully controlled by the operator. In both cases, the NE needs to traverse the Security Gateway(s) to access the nodes in the Secure Operator Network.

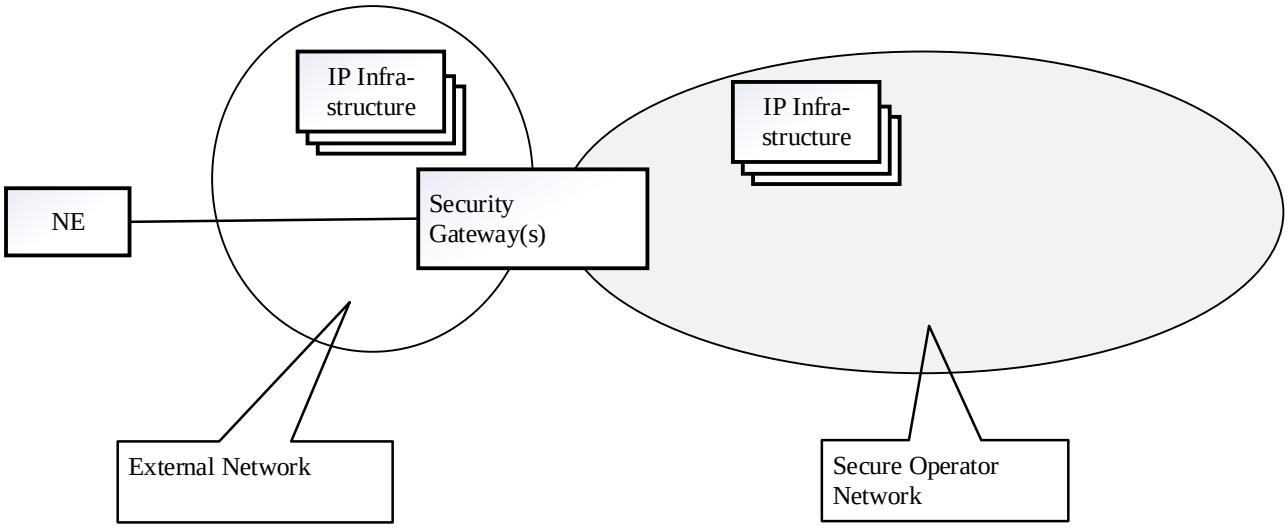


**Figure 4.1.2.2.1: NE connected to an External Network**

## 4.1.3 Security Aspects

### 4.1.3.1 Root Certificate Acquisition:

In accordance to TS 33.310 [2] clause 9.2 there are two options how to obtain the operator root certificate:

Option 1: The operator root certificate is provisioned in the NE prior to the CMPv2 protocol run.

Option 2: The operator root certificate is provisioned in the NE during the CMPv2 protocol run (as part of the Initialisation Response).

The required pre-provisioning in option 1 is against the basic idea of PnC to minimize pre-provisioning. Therefore from the PnC perspective Option 2 is more interesting. From a security point of view the following considerations are relevant:

- Option 2 has the risk that during the CMP initialisation a man-in the middle attack could take place. In order to be successful, such an attack happens timely during the actual CMP initialization run and the attacker has access to the access network between NE and RA/CA.
  This risk can be assessed as acceptable, given (a) the risks which are present at Options 1's prior provisioning – see below, (b) the short time window of vulnerability, (c) the closed access networks of many operators. In addition, most attacks will only lead to inability of the NE to connect to the network, or to misuse of the new NE by the attacker. The operator should notice it soon if the NE does not connect and will investigate the issue.

- Option 1 avoids the above "time window of vulnerability". On the other hand, it requires pre-provisioning of the operator root certificate, either in factory or on-site by service personnel. There is the risk of a security leak during the provisioning of the root certificate within the vendor / commissioning environment.

It seems questionable from a security point of view to allow option 2 also in public Internet (without operator-trusted access network). There the attacks stated above are more probable, and an attacker may even install some (static) catching or spoofing equipment in the public Internet to always capture such "initialization requests".

It is up to the network operator to choose the option with is preferable from his point of view (risk assessment, Plug and Connect importance).

The enrolment of NE shall use the CMPv2 protocol as specified in RFC 4210 [3] and RFC 4211 [4]. Security mechanism is further specified in TS 33.310 [2] clause 9.3.

### 4.1.3.2 Number of CA servers

There could be one or more RA/CA server, e.g. one per NE vendor. If more than one RA/CA server is deployed with one RA/CA server per vendor then the vendor identification would be needed either in the FQDN of the RA server or in the information from the IP AutoConfiguration Service carrying the information about RA/CA server.

#### 4.1.3.3 Number of OAM SeGWs

There could be one or more OAM SeGW, e.g. one per NE vendor. If more than one OAM SeGW is deployed with one OAM SeGW per vendor then the vendor identification would be needed either in the FQDN of the OAM SeGW or in the information from the IP AutoConfiguration Service carrying the information about OAM SeGW.

# 5 Business Level Requirements

## 5.1 Business Requirements for Plug and Connect

**REQ_PnC_CON_1** Plug and Connect shall use standard protocols.

**REQ_PnC_CON_2** VPN tunnels needed for Plug and Connect shall be set-up automatically.

**REQ_PnC_CON_3** The complete key management during Plug and Connect shall be a fully automatic secure procedure, based on procedures defined by 3GPP SA3.

**REQ_PnC_CON_4:** It shall be possible to perform the Plug and Connect procedures using secure protocols and procedures between the NE and OAM.

**REQ_PnC_CON_5** An NE shall be able to get its own IP addresses and SCS IP address without manual configuration.

**REQ_PnC_CON_6** For Plug and Connect the SCS shall only be accessible by authenticated and authorized NEs.

**REQ_PnC_CON_7** For Plug and Connect the initial and final configuration of the NE (or the information how to retrieve them) shall only be accessible by authenticated and authorized NEs.

**REQ_PnC_CON_8** The Plug and Connect solution shall be usable for IPv4-only networks, for IPv6-only networks and for dual stack IP networks.

**REQ_PnC_CON_9** Plug and Connect procedures shall support connection of NEs with and without NAT and via External Networks or Non-Secure Operator Networks.

# 6 Specification Level Requirements

## 6.1 Use Cases

### 6.1.1 Use case Plug and Connect

**Table 6.1.1.1**

| Use Case Stage | Evolution / Specification | <<Uses>> Related use |
|---|---|---|
| Goal | After physical installation, connect the NE to its SCS as automatically as possible. | |
| Actors and Roles | NE as user.<br>In this use case NE is the RAN NE. Other types of NE might also be compliant and use this use case. Examples of NEs are:<br>- gNB<br>- eNB<br>The NE within virtualization is not addressed. | |
| Telecom resources | NE; IP networks: Non-Secure Operator Network, External Network, and its elements like DHCP server optionally DNS, CA/RA servers, Security Gateway(s) (each protecting one or more Secure Operator Networks), Secure Operator Network(s) including SCS(s) | |

| Use Case Stage | Evolution / Specification | <<Uses>> Related use |
|---|---|---|
| Assumptions | There is a functional power supply for the NE.<br>There may be one or more IP Autoconfiguration Services like DHCP and Router Advertisements and zero or more DNS servers. | |
| Pre conditions | The NE is physically installed.<br>IP connectivity exists between the involved telecom resources.<br>The involved telecom resources are functional.<br>The relevant information is stored and available:<br>- Vendor Certificate at the NE<br>- Operator Certificate at the CA/RA<br>- For the External Network or Non-Secure Operator Network:<br>- (Outer) IP autoconfiguration information at the IP Autoconfiguration Service<br>- FQDN of the initial OAM SeGW at the NE<br>and/or<br>FQDN or IP address of the initial OAM SeGW at the IP Autoconfiguration Service<br>- FQDN of the CA/RA servers at the NE<br>and/or<br>FQDN or IP address of the CA/RA servers at the IP Autoconfiguration Service<br>- If FQDNs need to be resolved, corresponding IP address(es) at the DNS server(s)<br>- For the Secure Operator Network:<br>- (Inner) IP autoconfiguration information at the IP Autoconfiguration Service or at the initial OAM SeGW<br>- FQDN or IP address of the initial SCS at the NE and/or DHCP Server of the Secure Operator Network.<br>- If FQDNs need to be resolved, corresponding IP address(es) at the DNS server(s)<br>- Configuration and software for the NE at the SCS(s) | |
| Begins when | The NE is powered up. | |
| Step 1 (M) | If a VLAN ID is available the NE uses it. Otherwise the NE uses the native VLAN where PnC traffic is sent and received untagged | |
| Step 2 (M) | The NE acquires its IP address through stateful or stateless IP autoconfiguration. This may provide 0 or more DNS server addresses. | |
| Step 3 (M) | The NE acquires the IP address of the CA/RA server. The FQDN of the CA/RA server may be pre-configured in the NE or the FQDN or IP address of the CA/RA server may be provided by the IP Autoconfiguration Service. FQDNs are resolved through the DNS if necessary. Information provided by the IP Autoconfiguration Services shall supersede those pre-configured at the NE. | |
| Step 4 (M) | The NE performs Certificate Enrolment. | |
| Step 5 (M) | The NE acquires the IP address of the OAM SeGW. The FQDN of the OAM SeGW may be pre-configured in the NE or the FQDN or the IP address of the OAM SeGW may be provided by the IP Autoconfiguration Service. FQDNs are resolved through the DNS if necessary. | |
| Step 6 (M) | The NE establishes a secure connection (tunnel) to the Security Gateway given by Step 5.<br>The NE receives its (inner) IP autoconfiguration information (which may be the same as the outer IP address obtained in step2) and optionally the address of one or more DNS servers within the Secure Operator Network from the Configuration Parameters of IKEv2 during tunnel establishment. | |
| Step 7 (M) | The NE acquires the IP address of the correct Element Manager by either, issuing a DHCP request including the NE's vendor information, resolving FQDNs via DNS if necessary, or by having a pre-configured FQDN (including the NE's vendor information) resolved via DNS. | Secure connection |
| Step 8 (M) | The NE establishes a connection to the provided SCS and acquires its configuration and software if any.<br>The configuration may contain an address to another SCS that this specific node shall use as SCS.<br>The configuration may contain an address to another SeGW that should be used before connecting to the SCS.<br>The NE may then<br>- release the connection to the current SCS and OAM SeGW and then restart (returning to step 1),<br>- release the connection to the current SCS and OAM SeGW and then return to step 6,<br>- release the connection to the current SCS and then repeat step 8. | Secure connection |
| Ends when | Ends when all mandatory steps identified above are successfully completed or when an exception occurs. | |

| Use Case Stage | Evolution / Specification | <<Uses>> Related use |
|---|---|---|
| Exceptions | One of the steps identified above fails. | |
| Post Conditions | One or more secure connections exist between the NE and the SCS. Via the connection to the SCS the NE can receive further instructions to become operational and carry user traffic, e.g. the administrativeState is set to "unlocked". | |
| Traceability | All requirements of clauses 5.1 and 6.2.1. | |

Security aspects – e.g. prevention of unauthorized network access and of fake parameters supplied to the NEs, etc. - have special importance. Security related sub-steps to establish secure connections are not shown in table 6.1.1.1. More security aspects are described in clause 4.1.3.

## 6.2 Requirements

### 6.2.1 Specification Requirements for Plug and Connect

**REQ_PnC_FUN_1** The establishment of secure tunnels from the NE to the OAM shall support NAT traversal.

# Annex A (informative): Graphical representation of the PnC Use Case

The NE Plug and Connect procedure, given in clause 6.1.1 are classified into two sets corresponding to those conducted at External Network (or Non-secure Operator Network) and those conducted at the Secure Operator Network. An interpretation of these procedures is depicted in figures A.1 and A.2 respectively.

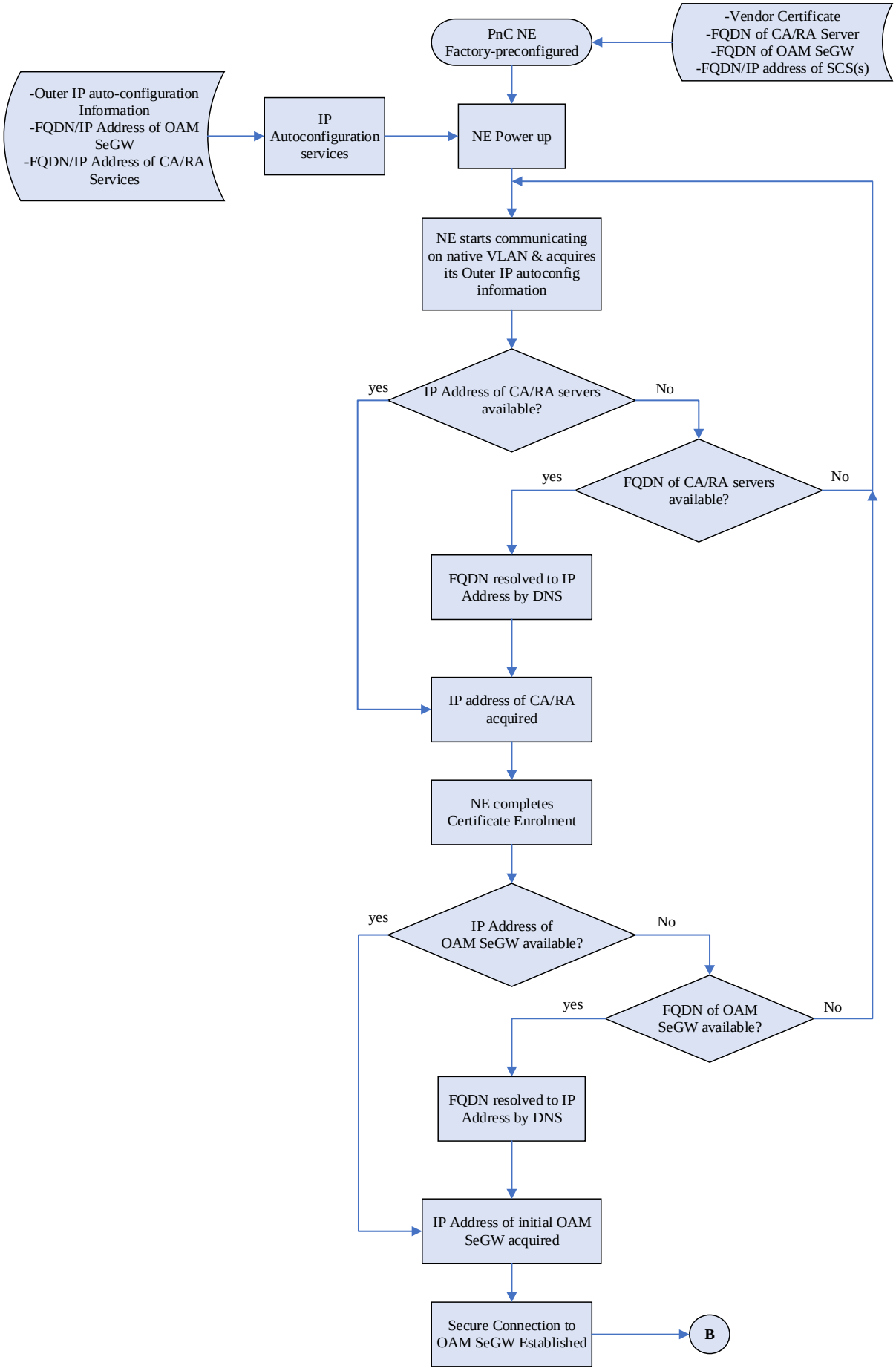


**Figure A.1: PnC procedure for the External Network or Non-secure Operator Network**

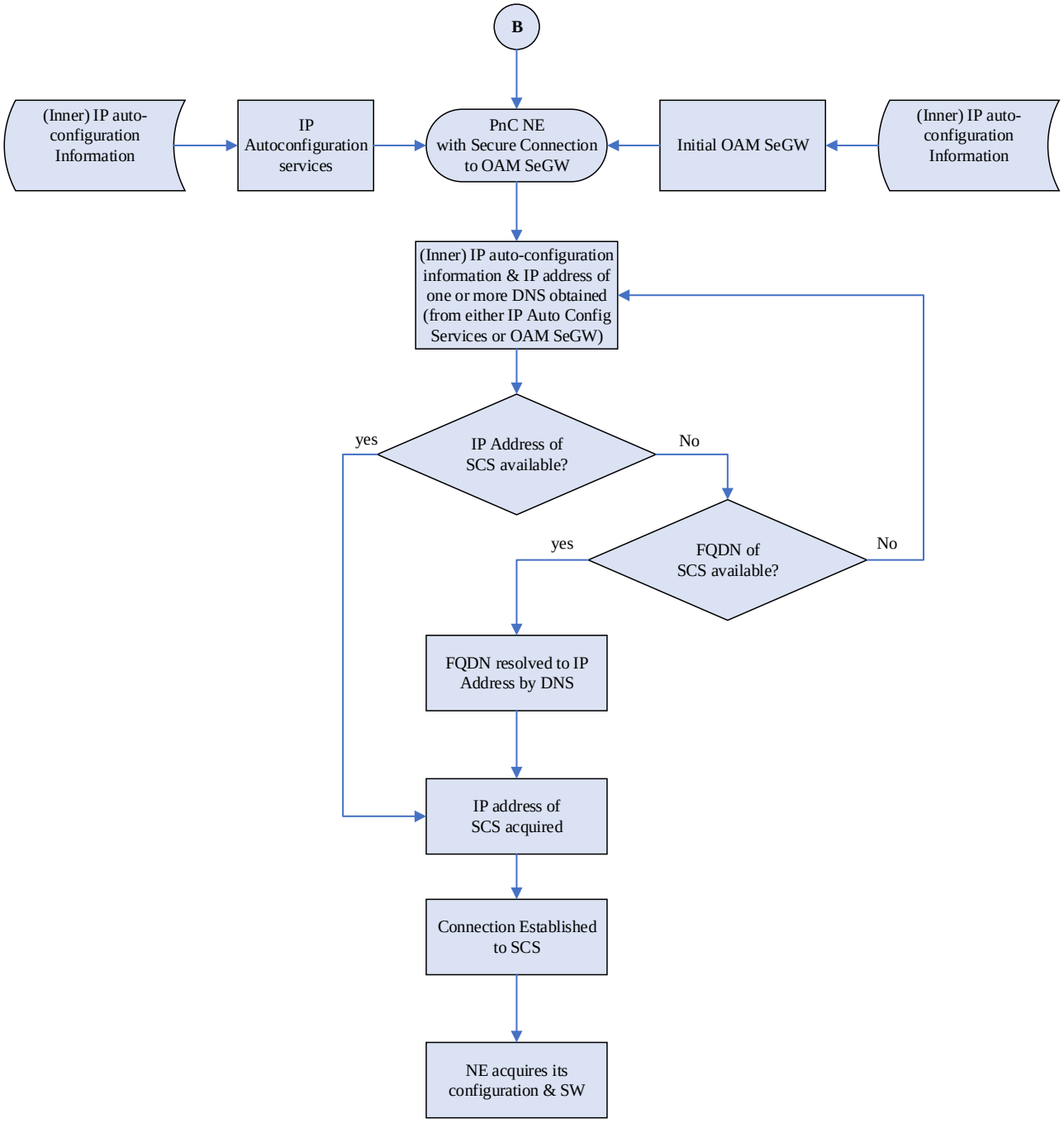


**Figure A.2: PnC Procedure for the secure Operator Network**

# Annex B (informative): Change history

| Change history | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | Meeting | TDoc | CR | Rev | Cat | Subject/Comment | New version |
| 2021-06 | SA5#137-e | S5-213662 | | | | | 0.1.0 |
| 2021-09 | SA5#138-e | S5-214659 | | | | | 0.2.0 |
| 2021-10 | SA5#139-e | S5-215628 | | | | | 0.3.0 |
| 2021-12 | SA5#140-e | S5-216602 | | | | | 0.4.0 |
| 2022-01 | SA5#141-e | S5-221749 | | | | | 0.5.0 |
| 2022-03 | SA#95e | SP-220122 | | | | Presented for information and approval | 1.0.0 |
| 2022-03 | SA#95e | | | | | Upgrade to change control version | 17.0.0 |
| 2024-04 | - | - | - | - | - | Update to Rel-18 version (MCC) | 18.0.0 |

# History

| Document history | | |
|---|---|---|
| V18.0.0 | May 2024 | Publication |
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