Multi-Access Gateway – controller

Release 25.3

Overview Guide

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Nokia is committed to diversity and inclusion. We are continuously reviewing our customer documentation and consulting with standards bodies to ensure that terminology is inclusive and aligned with the industry. Our future customer documentation will be updated accordingly.

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1 Getting started

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1.1 About this guide

This document provides an overview of the Nokia control and user plane separation (CUPS) solution. The Nokia Multi-Access Gateway – controller (MAG-c) functions as the control plane (CP) and has the ability to control SR OS-based user planes (UPs). The various UP functions include the broadband network gateway (BNG), the combined service gateway/packet data gateway (SGWSGW-U/PGWPGW-U), and the 5G user plane function (UPF).

Note: This guide generically covers content for the release specified on the title page of the guide, and may also contain some content that will be released in later maintenance loads. See the applicable *MAG-c Release Notes* for information about features supported in each load of the software release.

Note: The information in this guide is intended to be used in conjunction with the SR OS software user guides. The SR OS software user guides describe SR OS service features that are supported by the MAG-c. See the *7450 ESS, 7750 SR, 7950 XRS, and VSR Documentation Suite Overview Card 20.10.R1* for specific guide titles.

1.2 Conventions

This section describes the general conventions used in this guide.

1.2.1 Precautionary and information messages

The following information symbols are used in the documentation.

DANGER: Danger warns that the described activity or situation may result in serious personal injury or death. An electric shock hazard could exist. Before you begin work on this equipment, be aware of hazards involving electrical circuitry, be familiar with networking environments, and implement accident prevention procedures.

WARNING: Warning indicates that the described activity or situation may, or will, cause equipment damage, serious performance problems, or loss of data.

Caution: Caution indicates that the described activity or situation may reduce your component or system performance.

Note: Note provides additional operational information.

Tip: Tip provides suggestions for use or best practices.

1.2.2 Options or substeps in procedures and sequential workflows

Options in a procedure or a sequential workflow are indicated by a bulleted list. In the following example, at step 1, the user must perform the described action. At step 2, the user must perform one of the listed options to complete the step.

Example: Options in a procedure

1. User must perform this step.
2. This step offers three options. User must perform one option to complete this step.
   - This is one option.
   - This is another option.
   - This is yet another option.

Substeps in a procedure or a sequential workflow are indicated by letters. In the following example, at step 1, the user must perform the described action. At step 2, the user must perform two substeps (a. and b.) to complete the step.

Example: Substeps in a procedure

1. User must perform this step.
2. User must perform all substeps to complete this action.
   a. This is one substep.
   b. This is another substep.

2 Introduction to CUPS

CUPS is an architecture that gains popularity in the mobile core. The architecture was first adopted in the 4G Long Term Evolution (LTE) mobile core and later became the standard architecture for the 5G core. In 2019, BBF began a BNG CUPS project and subsequently standardized the BNG CUPS architecture in TR-459, TR-459.2, and TR-459.3. BBF continues to define new standardized features and solutions contributed by service providers and vendors.

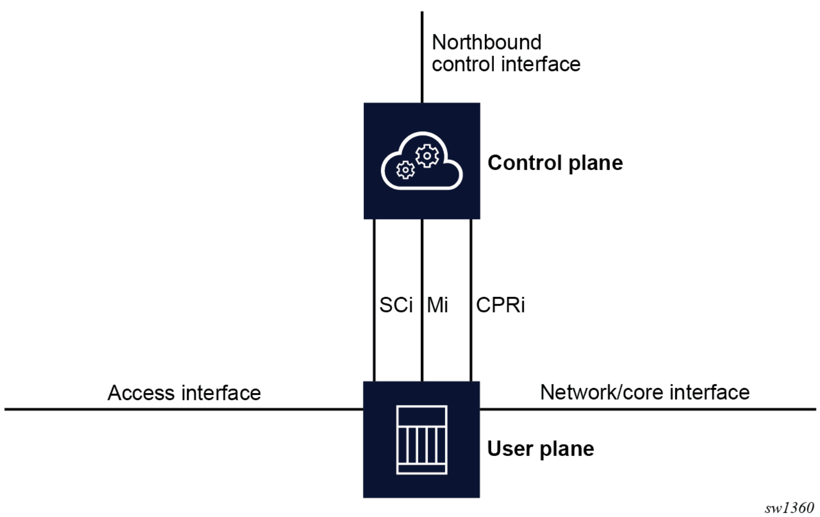
2.1 BNG CUPS

Nokia offers the standard BNG CUPS features defined by BBF. The Nokia CUPS solution includes fixed wireless access (FWA) and resiliency solutions. The following figure shows a high-level CUPS architecture as defined in TR-459.

The interfaces between the CP and the UP are:

- state control interface (SCi)
- control packet redirect interface (CPRi)
- management interface (Mi)

Figure 1: General CUPS architecture



BBF defines BNG CUPS as a disaggregated BNG (DBNG) where the CP of the DBNG is known as the DBNG-CP and the UP of the DBNG is known as the DBNG-UP. The following terms are used interchangeably in the industry:

- DBNG and BNG CUPS
- user plane (UP) and data plane (DP)

2.1.1 DBNG-CP overview

The DBNG-CP provides subscriber management functions including authentication, authorization, and accounting (AAA), IP address management, and policy management. The DBNG-CP has northbound control interfaces (NCIs) to communicate with external systems such as remote authentication dial in user service (RADIUS) servers and policy services. The DBNG-CP uses standard interfaces defined in TR-459 to interact with DBNG-UP like programing data traffic forwarding rules.

Note: Subscriber routing, including the IGP or BGP routing control plane, is located on the UP only. CUPS is only applicable to the subscriber management function within the BNG.

2.1.2 DBNG-UP overview

The UP is responsible for subscriber data traffic forwarding. The UP performs the following key functions:

- traffic management, including NAT and multicast replication
- policy enforcement
- subscriber statistics collection

The UP installs the subscriber forwarding rules communicated by the CP through the SCi.

Note: For the DBNG architecture, the subscriber routing function, which includes the IGP and BGP routing control and packet forwarding, remains entirely on the DBNG-UP. The DBNG-CP is not involved in any subscriber routing process.

2.1.3 DBNG interfaces

State control interface

The state control interface (SCi) is responsible for programming subscriber data forwarding rules on the UP. The CUPS solution uses the 3GPP packet forwarding control protocol (PFCP) protocol as specified in 3GPP TS 29.244. 3GPP designed the PFCP to be fully extensible. To accommodate the broadband wireline use case, BBF extended the PFCP information elements (IEs) and published the extension in TR-459. Nokia extended the PFCP IE set to offer additional feature sets.

For wireline access, the SCi programs, at minimum, the following two types of rules:

- control packet redirection rules – bidirectional rules to redirect subscriber wireline control packets, via the UP, from the residential gateway (RG) to the CP and from the CP to the RG
- subscriber data forwarding rules – bidirectional rules to forward subscriber traffic between the access interface and the network interface

  Note: The terms "network interface" and "core interface" are used interchangeably in the industry.

See the *MAG-c PFCP Interface Description Guide* for more information about the SCi and the PFCP.

Control packet redirect interface

The purpose of the control packet redirect interface (CPRi) is to tunnel the control packets of the RG that are received on the UP to the CP and from the CP to the UP and back to the RG. The tunnel encapsulation is the GPRS tunneling protocol - user plane (GTP-U) as specified in 3GPP TS 29.244. GTP-U is extended with an optional network service header (NSH) as defined in RFC 8300 to carry UP-specific metadata such as the ingress port. There are two types of CPRi tunnels:

- per-session CPRi tunnels
- common CPRi tunnels

The SCi installs each CPRi tunnel on the UP.

Note: The terms "CPRi" and "IBCP" (the Nokia in-band control plane) are used interchangeably; both indicate the same interface and function.

See the *MAG-c PFCP Interface Description Guide* for more information about the CPRi and GTP-U.

Management interface

The DBNG-CP uses the management interface (Mi) to program the DBNG-UP for everything that is not related to subscriber forwarding rules. BBF TR-459 has no specifications for this interface.

3 Nokia multi-access broadband CUPS solution

The Nokia cloud-based converged broadband CUPS architecture enhances the triple play service delivery architecture (TPSDA). The MAG-c implements both the fixed access and fixed wireless access (FWA) CP functions. The SR OS-based BNG implements both the fixed access and FWA UP functions.

3.1 Evolution of the BNG

The Nokia SR OS TPSDA originated as a BNG providing traditional broadband services such as high speed Internet (HSI), voice over IP (VoIP), IPTV, wholesale/retail, and network address translation (NAT).

Over the years, the broadband access demand evolved beyond traditional wireline access and into wireless access. The Nokia BNG evolved to support the Wi-Fi gateway function, the FWA function, and the hybrid access gateway (HAG) function.

Driven by the market, the BNG technology evolved further into a CUPS architecture. The Nokia multi-access broadband CUPS solution disaggregates the Nokia BNG and all its functions. The MAG-c implements the CP element. The Nokia BNG implements the UP function to handle datapath forwarding of the broadband wireline and the FWA functions. Operators can select the best UP type that fits the targeted applications:

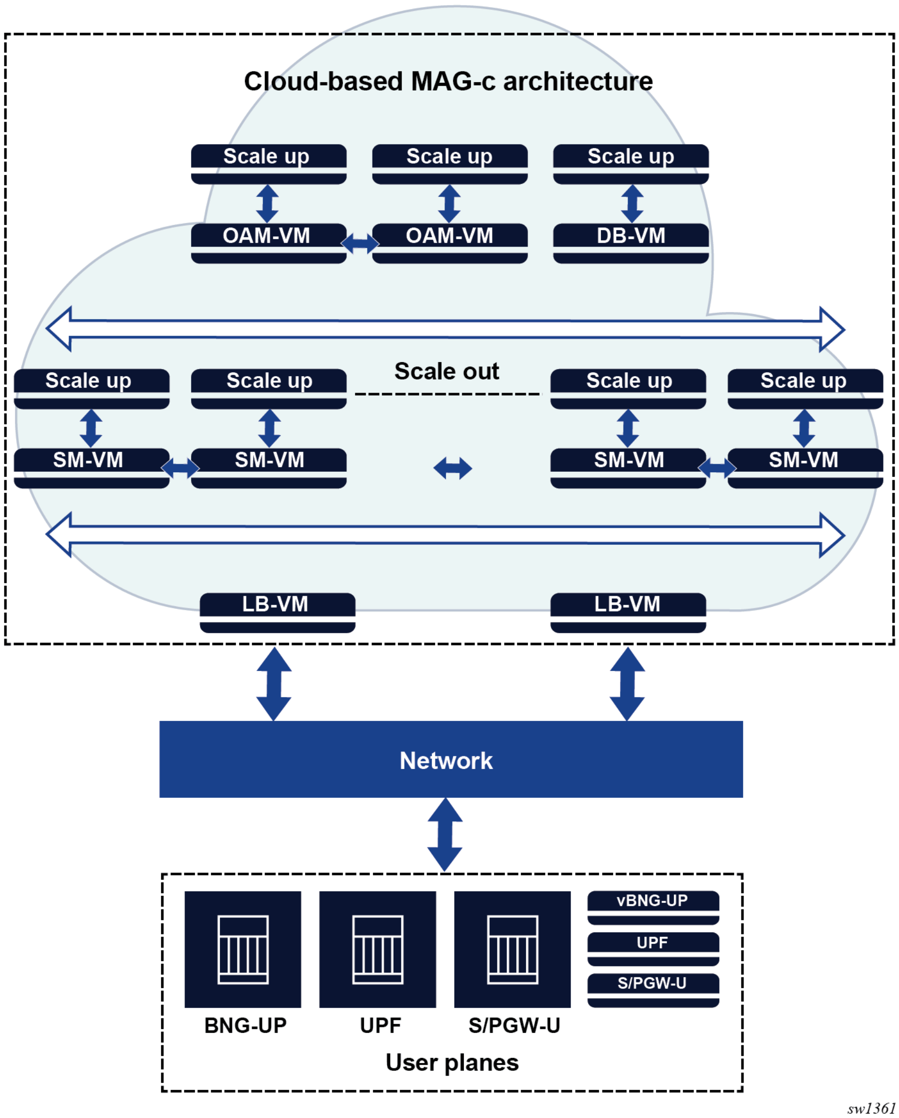
- Virtualized Service Routers (VSRs)
- physical Service Routers (SRs)
- a combination of both

3.2 Cloud-based MAG-c architecture

The following figure shows the overall Nokia multi-access CUPS architecture, with the following virtualized network functions (VNFs) of the MAG-c:

- operation and maintenance virtual machine (OAM-VM) – management interface for the MAG-c configuration
- database virtual machine (DB-VM) – common storage for all subscriber session state
- session management virtual machine (SM-VM) – subscriber management function and processing
- load balancing virtual machine (LB-VM) – load distribution to various SM-VMs

Figure 2: The cloud-based MAG-c architecture



See the *MAG-c Installation Guide* for more information about the MAG-c architecture and installation.

3.3 UP overview

The Nokia SR OS based BNG can act as a UP for the MAG-c. The VSR and the SR platforms support the UP functions. The Nokia BNG supports the following UP functions when acting as a UP:

- BNG UP function (BNG-UP)
- 5G UP function for 5G FWA (FWA-UP)
- 4G combined SGW UP function (SGW-U) and PGW UP function (PGW-U) for 4G FWA

All SR OS platforms can simultaneously act as a UP and as a standalone BNG. In standalone BNG mode, all SR OS TPSDA features are supported, the following are some key enhanced subscriber management (ESM) features deployed today:

- broadband subscriber management services, IP over Ethernet (IPoE), point-to-point protocol over Ethernet (PPPoE), LAC, and LNS
- FWA
- NAT
- multicast
- public Wi-Fi
- HAG

4 Nokia value propositions

A CUPS architecture disaggregates session management between the CP and the UP. The CUPS architecture provides the advantage of independent scaling and independent life cycle management.

4.1 Simplifying operation and maintenance

Because the disaggregation of the BNG into a CP and UP introduces more network elements to manage, the Nokia converged broadband CUPS solution greatly emphasizes management simplification:

- The management interface to operate, maintain, and manage the entire CUPS solution is simple, compact, and controlled.
- Grouping functions helps to process subscriber sessions efficiently and responsively.
- The solution is extensible to support additional convergence use cases in the future.

A traditional BNG is a single unit that contains both the CP and UP. When either the subscriber or the bandwidth scale grows, more BNGs are deployed to accommodate the growth. Even though, for example, bandwidth growth only requires more UP resources, the additional BNG provides additional unnecessary CP resources. In addition, because the BNGs are individually managed, any new service offering requires configuration changes to each individual BNG.

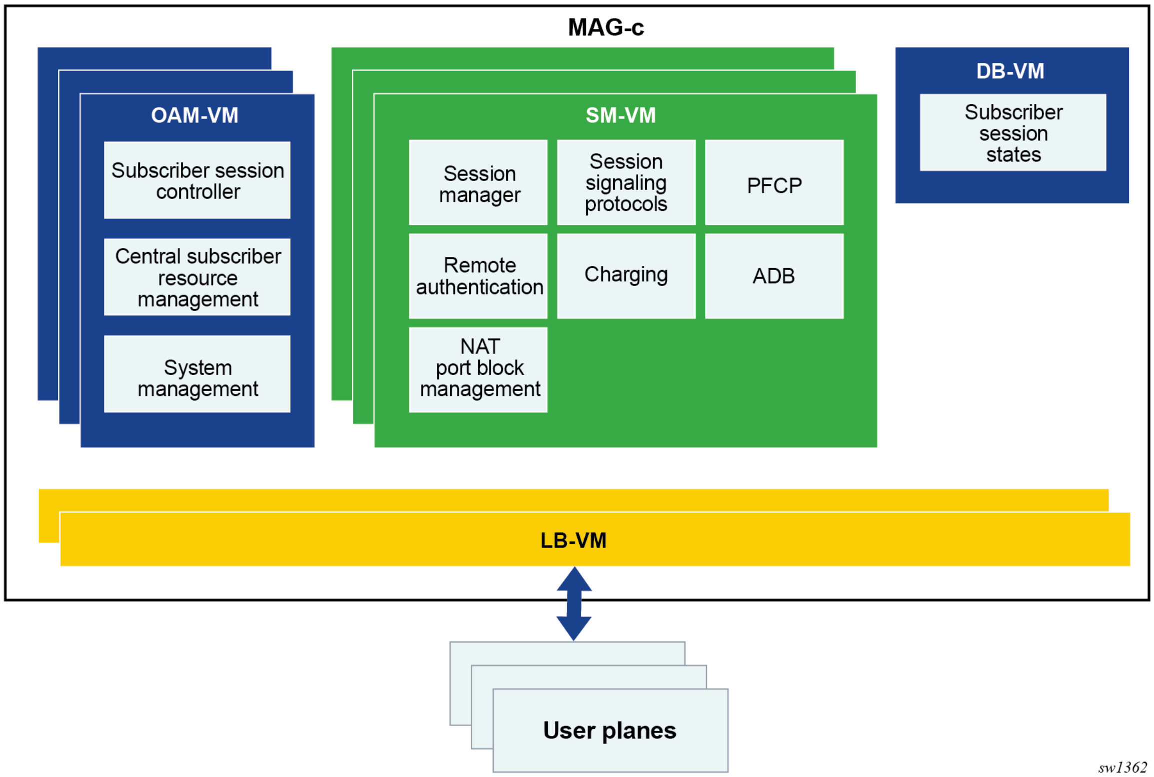
The MAG-c provides a centralized location for managing subscriber authentication, policies, and accounting settings. The solution requires minimal provisioning touches. Most configurations required on the UPs are performed one time, during commissioning. In production, the CUPS solution sets up subscriber forwarding with zero touch.

The MAG-c is the central brain of all UPs. The CP is kept up-to-date on the resource consumptions and the health status of the UPs, which allows the CP to make informed decisions about setting up or modifying subscriber sessions. For example, the MAG-c has all the real time information about the subscriber load on all the UPs and can:

- load balance new subscriber sessions among the UPs and ensure an even distribution
- determine if failing over to a new UP is necessary, during a failure event, depending on the remaining adequate resources

The following figure shows the functional blocks within a MAG-c and how the virtualized network function (VNF) components within the MAG-c are grouped. The grouping of the VNF components into specific functional blocks is deliberate and ensures the most efficient subscriber session processing, simplifying both operations and management.

Figure 3: MAG-c



The grouping of functions within the OAM-VM provides a single point of system management:

- The central subscriber resources management provides IP pool address management.
- The subscriber session controller provides operations on the session information of active subscribers and enforces common policies such as limits on the number of active subscribers.

The grouping of the common subscriber management functions within the SM-VM allows for efficient processing of subscriber session setup, modification, and tear down.

The SM-VM includes the following functional blocks:

- The session manager is responsible for managing IPoE, PPPoE, layer 2 tunneling protocol access concentrator (L2TP LAC), and FWA sessions.
- The session signaling protocols functional block includes dynamic host configuration protocol (DHCP), DHCP for IPv6 (DHCPv6), stateless address auto-configuration (SLAAC), GPRS tunneling protocol (GTP), PPPoE discovery, link control protocol (LCP), network control protocol (NCP), password authentication protocol (PAP), and challenge handshake authentication protocol (CHAP).

The LB-VM solely performs the balancing of control packets and can automatically accommodate the scaling in and out of the OAM-VM and SM-VM independently.

The DB-VM stores the subscriber session state sent by the SM-VMs. If one or more SM-VMs fail, the DB-VM provides the full subscriber session state to the backup SM-VMs.

The MAG-c architecture allows flexibility for accommodating future needs. New functional blocks can be added to the SM-VM to support additional broadband use cases and to the OAM-VM for further management improvements.

See the *MAG-c Control Plane Function Guide* for more information about the MAG-c.

4.2 Single northbound IP interface for external systems

Traditionally, scaling up the BNG also requires the AAA servers to handle more interfaces to the BNGs. Continual investment in the IT network infrastructure is required to accommodate new connectivity between the BNGs and the AAA servers, the external DHCP servers, and the policy servers.

The Nokia MAG-c solution addresses this problem by presenting a single northbound interface to the AAA servers and the policy servers in scale-up or -down scenarios. This reduces the IT infrastructure for back-end systems. One source IP address on the MAG-c represents the entire converged network. The CP also provides a single IP address for requests coming from a remote authentication system; for example, for unsolicited authorization change requests such as the RADIUS Change of Authorization (CoA) messages.

See the *MAG-c Control Plane Function Guide* for more information about authentication.

4.3 Centralized resource management

On traditional BNGs, the IP address pools need to be defined and pre-allocated to individual BNGs. Subscriber growth can complicate the IP address pool redistribution, especially when the availability of IPv4 public addresses is limited.

The Nokia MAG-c solution tackles this problem by providing a centralized subscriber resource management platform. Resources such as IP addresses are claimed on an on-demand basis using the on-demand subnet allocation (ODSA) address assignment system. ODSA eliminates the operational burden of pre-allocating dedicated pools to BNG-UPs. ODSA is applicable for all pool address management including DHCPv4, PPPoE IPv4 addresses, DHCPv6, and the SLAAC prefix pool. Because IP subnets are not pre-allocated to individual BNGs, there are no idle subnets in the BNG-UPs. Addresses and prefixes are dynamically allocated to the BNG-UPs that require them most, which minimizes the waste of IP addresses and prefixes.

ODSA automatically accounts for BNG-UP resiliency and eliminates any address pool pre-planning.

See the *MAG-c Control Plane Function Guide* for more information about address assignment.

4.4 Centralized resources for NAT

Traditionally, IPv4 public address pools are pre-allocated per BNG. The MAG-c is a centralized management point and assigns public address subnets to BNG-UPs in real time, ensuring no waste of IPv4 public addresses. The MAG-c uses the ODSA system for allocating these public address subnets.

Public address subnet assignment automatically accounts for BNG-UP resiliency and eliminates any NAT public pool pre-planning.

NAT logging is centralized and integrated into subscriber accounting where the MAG-c interfaces with the RADIUS accounting back-end systems.

See the *7750 SR and VSR BNG CUPS User Plane Function Guide* and the *MAG-c Control Plane Function Guide* for more information about carrier-grade NAT (CGNAT).

4.5 Flexible authentication and authorization flows

The BNG provides a variety of authentication and authorization options, including:

- locally provisioned authentication and authorization policies
- mobile-based authentication such as home subscriber server (HSS) or unified data management (UDM)
- wireline-based authentication such as RADIUS
- a combination of the above

The following are examples of authentication requirements for a multi-access BNG:

- Provide local authentication policies.
- Provide remote authentication AAA servers. Select the AAA servers based on the use case.
- Support RADIUS-based and SBI-based AAA servers.
- Group and identify subscribers by authentication option; that is, subscribers that require wireline authentication versus those that require wireless authentication.
- Support multiple authentication sequences for a single subscriber session (for use cases such as wholesale and retail).

Example requirements for policy control:

- Retrieve subscriber policies locally or remotely.
- Support AAA servers and policy and charging rules function (PCF/CHF) servers for the retrieval of remote policies.
- Support the concatenation of various policy rules retrieved from different policy servers to form a subscriber policy.

The MAG-c provides an authentication database (ADB) for full flexibility in authentication and policy enforcement. The ADB accommodates any complex sequencing of authentication and policy control and provides the ability to define a flow for a single subscriber or a group of subscribers. Multiple ADBs can be accessed in sequence to accommodate multiple authentication and authorization sources.

See the *MAG-c Control Plane Function Guide* for more information about the ADB.

4.6 Independent life cycle management and scaling of the CP and UP

Traditionally, the BNG is offered as a single chassis, where the CP and UP are bundled together as a single unit. When the CP or UP capacity is reached, there are few options but to install a new chassis or new line cards.

The CP can be a limiting factor on subscriber scale. The SR OS control plane module (CPM) is often required to process and generate many control packets, such as authentication messages, accounting records, log events, and keep-a-live signaling. In addition, a multi-access gateway that processes FWA subscribers, hybrid access subscribers, and Wi-Fi subscribers requires additional CP processing power for control messages signaling.

SM-VMs in the MAG-c architecture can be scaled up and out to handle more capacity. When scaling SM-VMs up or out to accommodate the subscriber load, the number of OAM-VMs does not need to increase, which allows the system to maintain a single point of management.

The Nokia MAG-c solution provides flexibility to UP capacity scaling. The UP can be scaled up without the confinement of a chassis. All UP platforms or new UP platforms are managed by a single MAG-c. Service providers can select the UP platform that best serves the use case, and the MAG-c can manage any mix of UP platforms.

See the *MAG-c Installation Guide* for more information about CP scaling.

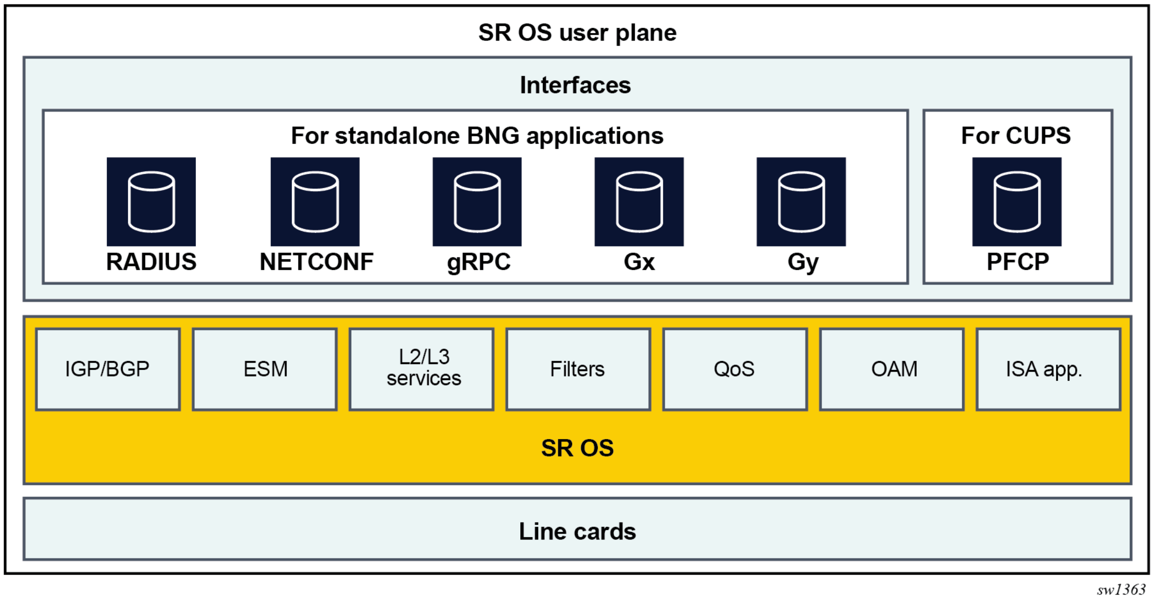
4.7 Dual role of UPs

All SR OS platforms can simultaneously act as a UP and as a standalone BNG. In standalone BNG mode, all SR OS TPSDA features are supported including ESM, wireless local area network - gateway (WLAN-GW), FWA, HAG, and virtual routed gateway (vRGW). In other words, any BNG in the production network can both serve as a UP when a PFCP SCi interface is added and serve as a standalone BNG. When a BNG takes on the additional UP function, the existing BNG services in production are not impacted.

To enable a platform to support the UP function, minimal commissioning configuration is required. The UP typically requires no additional configuration after it is commissioned.

The following figure shows the common broadband interfaces supported on the UP and the key applications supported on the SR OS. The UP can serve as a standalone BNG supporting all the classic management interfaces including RADIUS, network configuration protocol (NETCONF), gRPC remote procedure call (gRPC), Gx, and Gy. At the same time, the UP can support PFCP for the MAG-c applications.

Figure 4: The UP



See the *7750 SR and VSR BNG CUPS User Plane Function Guide* for more information about UPs.

4.8 Nokia multi-access broadband CUPS use cases

The MAG-c supports the following broadband use cases:

- IPoE dual stack
- PPPoE dual stack
- L2TP LAC
- CGNAT
- data-trigger subscribers
- static IP subscribers
- FWA

4.9 CUPS use cases for fixed wireline wireless convergence

The MAG-c CUPS solution supports the following converged use cases:

- 4G FWA
- 4G and 5G non-standalone (NSA) option 3 FWA
- 5G standalone (SA) FWA

The MAG-c can take the roles of multiple CP functions including DBNG-CP, PGW CP function (PGW-c), SGW CP function (SGW-c), and session management function (SMF). Any Nokia SR OS platform can take on the role of UP and contains all of the following functions:

- BNG-UP
- combined PGW-U/SGW-U
- 5G UPF

The multi-functional CP and UP are possible because both broadband wireline and mobile wireless access use the standard defined 3GPP PFCP protocol for the SCi interface. 3GPP specifies the use of PFCP for the 4G and 5G core while BBF specifies the use of PFCP for wireline and converged access CUPS architectures.

4.10 High availability support

The Nokia multi-access broadband CUPS solution supports both CP resiliency and UP resiliency.

MAG-c resiliency architecture

MAG-c supports geo-redundancy which enables minimal service impact during CP software upgrades. The CP also supports intra-VNF resiliency.

See the *MAG-c Control Plane Function Guide* for more information about the CP geo-redundancy installation.

UP resiliency architecture

UP resiliency ensures minimal impact to the subscriber sessions for various types of UP failures, including:

- link failure
- line card failure
- chassis failure

CUPS enables multiple resiliency models such as 1:1 active hot standby and N:1 active warm standby.

See the *MAG-c Control Plane Function Guide* for more information about UP resiliency.

UP headless mode

The Nokia CUPS solution accounts for failure conditions where the CP and UP are only briefly disconnected. In this use case, the UP loses its connectivity to the CP and becomes headless. During the headless period, the UP continues to service all connected sessions. After the path between the CP and UP is restored, the CP ensures that all subscriber states are synchronized.

See the *7750 SR and VSR BNG CUPS User Plane Function Guide*, the *MAG-c Control Plane Function Guide*, and the *MAG-c PFCP Interface Description Guide* for more information about the headless mode.

4.11 Migration to CUPS

The UPs are all SR OS platforms providing the full SR OS feature sets, including all TPSDA features.

Any BNG in the production network can be configured to take on the additional role of a MAG-c controlled UP on a per-capture-SAP basis. All existing configurations on the BNG continue to function even when taking on the UP role. For example, it is possible to leave all existing customers on their respective service access points (SAPs) and dedicate some new SAPs to host new CUPS subscribers.

This flexibility allows for service providers to:

- selectively migrate subscribers from an existing SAP to a new CUPS-based SAP
- selectively migrate CUPS subscribers back to their original SAPs
- indefinitely maintain existing BNG subscribers on their existing SAPs

5 More information

Find references to documentation for more information about the MAG-c.

See the *MAG-c Guide to Documentation* or the *MAG-c Release Notes* for a list of guides with more information about the MAG-c installation, the CP function, the RADIUS attributes, and the PFCP.

See the *7750 SR and VSR BNG CUPS User Plane Function Guide* for more information about BNG-UP.

See the *MAG-c Release Notes* for a list of SR OS guides with more information about SR OS features.

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