FEATURE GUIDE

Ruckus LTE AP Feature Guide Release SC 03.00.00.00XX

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Preface

Document Conventions

The following table lists the text conventions that are used throughout this guide.

TABLE 1 Text Conventions

Convention	Description	Example
`monospace`	Identifies command syntax examples	`device(config)# interface ethernet 1/1/6`
bold	User interface (UI) components such as screen or page names, keyboard keys, software buttons, and field names	On the **Start** menu, click **All Programs**.
italics	Publication titles	Refer to the *Ruckus Small Cell Release Notes* for more information.

Notes, Cautions, and Safety Warnings

Notes, cautions, and warning statements may be used in this document. They are listed in the order of increasing severity of potential hazards.

NOTE

A NOTE provides a tip, guidance, or advice, emphasizes important information, or provides a reference to related information.

ATTENTION

An ATTENTION statement indicates some information that you must read before continuing with the current action or task.

CAUTION

A CAUTION statement alerts you to situations that can be potentially hazardous to you or cause damage to hardware, firmware, software, or data.

DANGER

A DANGER statement indicates conditions or situations that can be potentially lethal or extremely hazardous to you. Safety labels are also attached directly to products to warn of these conditions or situations.

Command Syntax Conventions

Bold and italic text identify command syntax components. Delimiters and operators define groupings of parameters and their logical relationships.

Convention	Description
bold text	Identifies command names, keywords, and command options.

Convention	Description
italic text	Identifies a variable.
[ ]	Syntax components displayed within square brackets are optional. Default responses to system prompts are enclosed in square brackets.
{ **x** | **y** | **z** }	A choice of required parameters is enclosed in curly brackets separated by vertical bars. You must select one of the options.
x | **y**	A vertical bar separates mutually exclusive elements.
< >	Nonprinting characters, for example, passwords, are enclosed in angle brackets.
...	Repeat the previous element, for example, *member*[*member*...].
\	Indicates a "soft" line break in command examples. If a backslash separates two lines of a command input, enter the entire command at the prompt without the backslash.

Document Feedback

Ruckus is interested in improving its documentation and welcomes your comments and suggestions.

You can email your comments to Ruckus at #Ruckus-Docs@commscope.com.

When contacting us, include the following information:

- Document title and release number
- Document part number (on the cover page)
- Page number (if appropriate)

For example:

- Ruckus SmartZone Upgrade Guide, Release 5.0
- Part number: 800-71850-001 Rev A
- Page 7

Ruckus Product Documentation Resources

Visit the Ruckus website to locate related documentation for your product and additional Ruckus resources.

Release Notes and other user documentation are available at https://support.ruckuswireless.com/documents. You can locate the documentation by product or perform a text search. Access to Release Notes requires an active support contract and a Ruckus Support Portal user account. Other technical documentation content is available without logging in to the Ruckus Support Portal.

White papers, data sheets, and other product documentation are available at https://www.ruckuswireless.com.

Online Training Resources

To access a variety of online Ruckus training modules, including free introductory courses to wireless networking essentials, site surveys, and Ruckus products, visit the Ruckus Training Portal at https://training.ruckuswireless.com.

Contacting Ruckus Customer Services and Support

The Customer Services and Support (CSS) organization is available to provide assistance to customers with active warranties on their Ruckus products, and customers and partners with active support contracts.

For product support information and details on contacting the Support Team, go directly to the Ruckus Support Portal using https://support.ruckuswireless.com, or go to https://www.ruckuswireless.com and select **Support**.

What Support Do I Need?

Technical issues are usually described in terms of priority (or severity). To determine if you need to call and open a case or access the self-service resources, use the following criteria:

- Priority 1 (P1)—Critical. Network or service is down and business is impacted. No known workaround. Go to the **Open a Case** section.
- Priority 2 (P2)—High. Network or service is impacted, but not down. Business impact may be high. Workaround may be available. Go to the **Open a Case** section.
- Priority 3 (P3)—Medium. Network or service is moderately impacted, but most business remains functional. Go to the **Self-Service Resources** section.
- Priority 4 (P4)—Low. Requests for information, product documentation, or product enhancements. Go to the **Self-Service Resources** section.

Open a Case

When your entire network is down (P1), or severely impacted (P2), call the appropriate telephone number listed below to get help:

- Continental United States: 1-855-782-5871
- Canada: 1-855-782-5871
- Europe, Middle East, Africa, Central and South America, and Asia Pacific, toll-free numbers are available at https://support.ruckuswireless.com/contact-us and Live Chat is also available.
- Worldwide toll number for our support organization. Phone charges will apply: +1-650-265-0903

We suggest that you keep a physical note of the appropriate support number in case you have an entire network outage.

Self-Service Resources

The Ruckus Support Portal at https://support.ruckuswireless.com offers a number of tools to help you to research and resolve problems with your Ruckus products, including:

- Technical Documentation—https://support.ruckuswireless.com/documents
- Community Forums—https://forums.ruckuswireless.com/ruckuswireless/categories
- Knowledge Base Articles—https://support.ruckuswireless.com/answers
- Software Downloads and Release Notes—https://support.ruckuswireless.com/#products_grid
- Security Bulletins—https://support.ruckuswireless.com/security

Using these resources will help you to resolve some issues, and will provide TAC with additional data from your troubleshooting analysis if you still require assistance through a support case or RMA. If you still require help, open and manage your case at https://support.ruckuswireless.com/case_management.

About this Document

Purpose

The document provides information on all features enabled on Ruckus LTE AP software till Release version SC 2.4.1.

Intended Audience

The document is intended for Ruckus partners and customer that deploy Ruckus LTE AP.

Abbreviations

The following table describes the abbreviations used in the document.

Abbreviation	Description
ACS	Auto-Configuration Server (TR-069 server)
AP	Access Point
CA	Carrier Aggregation - when used in context of data rate/ cell thorughput Also, Certificate Authority (part of a PKI) - when used in context with security & VPN/ IPsec.
CBRS	Citizen Broadband Radio Service
CMP	Certificate Management Protocol
CRL	Certificate Revocation List
DB	Database
DHCP	Dynamic Host Configuration Protocol
DL	Downlink
DNS	Domain Name System
EARFCN	E-UTRAN Absolute Radio Frequency Channel Number
EFS	Encrypted File System
EPC	Evolved Packet Core
FCC	Federal Communications Commission
FDD	Frequency Division Duplexing
FQDN	Fully Qualified Domain Name
GPB	Google Protocol Buffer
GPBS	Google Protocol Buffer Streaming
GPS	Global Positioning System
GUI	Graphic User Interface
HO	Handover

Abbreviation	Description
HTTPS	HyperText Transport Protocol Secure
LLDP	Link Layer Discovery Protocol
KPI	Key Performance Indicator
MAC	Media Access Control
MME	Mobility Management Entity
MQTT	Message Queuing Telemetry Transport
MSL	Message Service Layer
NL	Network Listen (to macrocell)
NTP	Network Time Protocol
OCSP	Online Certificate Status Protocol
PKI	Public key Infrastructure
PTP	Precision Timing Protocol
PSD	Power Spectral Density
RF	Radio Frequency
RPC	Remote Procedure Call
RRC	Radio Resource Control
RSP	Reference Signal Power
SAS	Spectrum Access System
SCTP	Stream Control Transmission Protocol
SFS	Secure File System
SSF-4	Special Subframe - 4
TDD	Time Division Duplexing
TLS	Transport Layer Security
UE	User Equipment
UL	Uplink
URL	Uniform Resource Locator

Ruckus LTE AP Overview

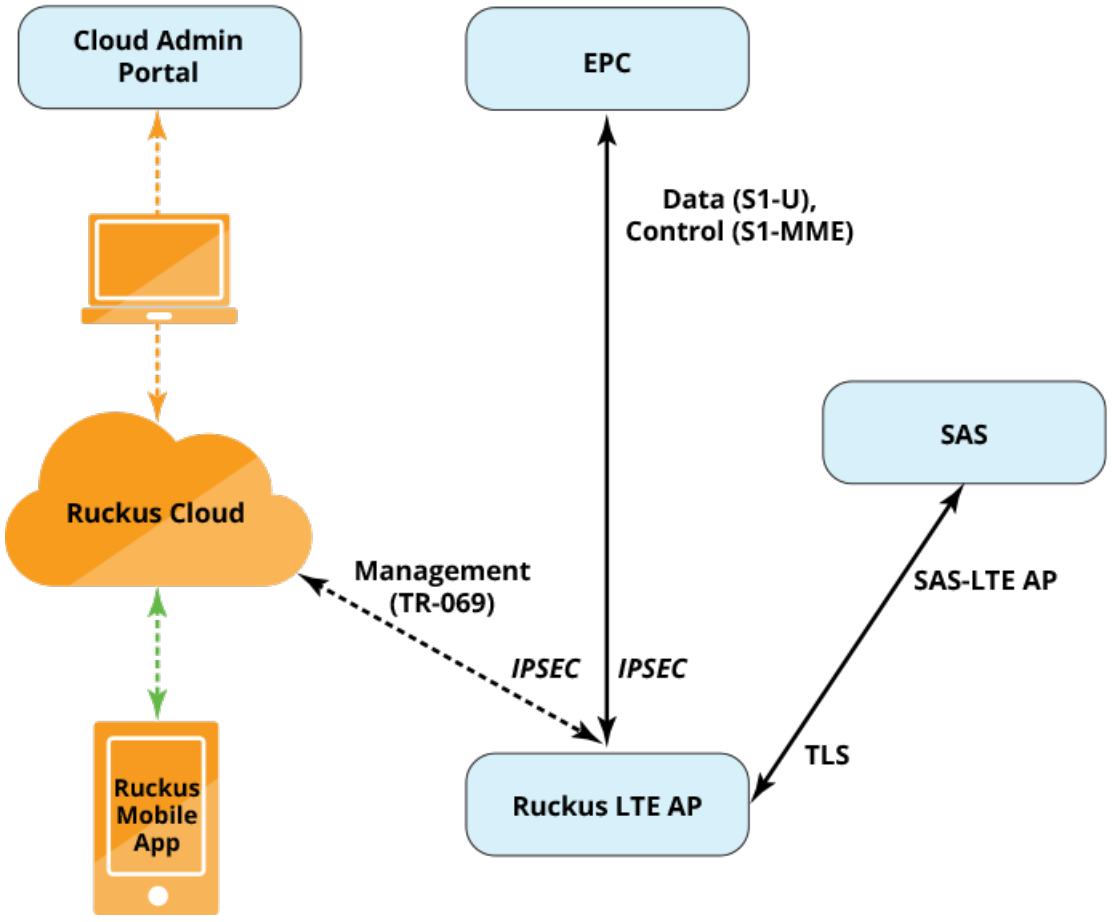
High Level Design

Ruckus offers LTE service via LTE Access Point (AP) . These are TD-LTE devices that operate in Band 48 - CBRS Band. LTE APs are shipped with factory-default configuration to communicate with Ruckus LTE AP Management service upon completing boot-up procedures once internet connectivity is established.

Ruckus LTE AP management is a cloud hosted service that can be accessed via browser. The portal allows you to create and configure a complete LTE network using options to configure LTE AP details through GPS location, PTP timing, EPC details, SAS information, and any other details. When configured correctly, after a successful bootup, AP connects to the above service and updates to latest firmware, inherits it's configuration and is ready to provide LTE service.

The following figure shows connectivity of the management, control, and data interfaces between Ruckus LTE AP and other network elements.

FIGURE 1 Ruckus OpenG Solution

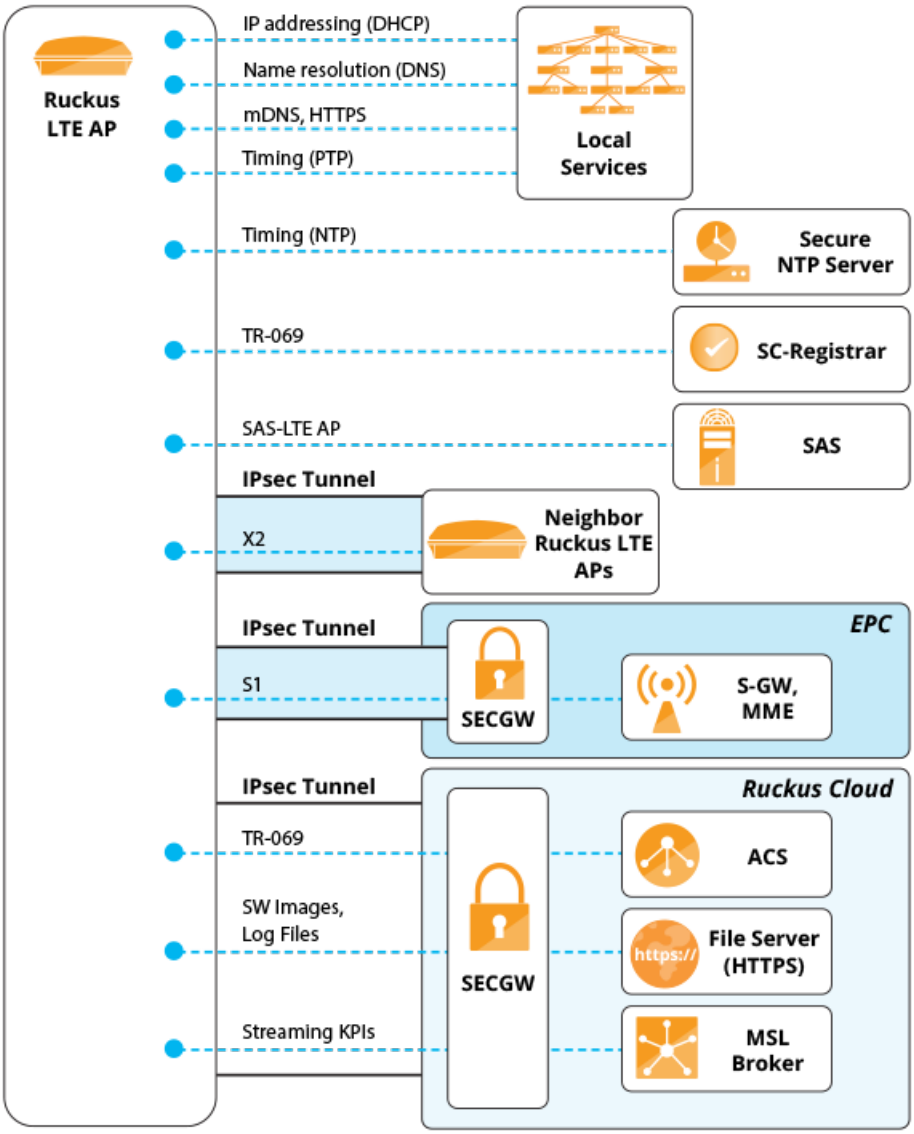


Each Ruckus LTE AP has a separate management as well as control/data interface for traffic. For secure communications, it is highly recommended that both interfaces be configured to communicate through security gateways over IPsec.

Ruckus LTE AP Interfaces

Following figure illustrates Ruckus LTE AP interfaces.

FIGURE 2 Ruckus LTE AP Interfaces



Following interfaces are represented in the figure.

- **Local Services:** There are four local services.
  - DHCP server, which allocates a local IPv4 address.

NOTE
All LTE APs within a venue should be L3-reachable and should be on the same VLAN.

- DNS for name resolution.
- NTP for initial synchronization of LTE APs date/time function.

NOTE
NTP is required for checking the validity interval on SecGW server certificates.

- PTP interface is not a part of IPsec tunnel.

- **IPsec Tunnels:** There are three or more IPsec tunnels. The outer source IP address of datagrams transmitted by LTE APs is the locally allocated IPv4 address.

NOTE
If LTE AP is behind a NAT firewall, its outer source IP will be public IP address of the network in case a packet leaves NAT environment.

  - **IPsec tunnel to AP Management:** The inner IP [source] address used by LTE AP for transmitting datagrams is allocated by IKE function of IPsec server. The outer destination address of the datagram transmitted by LTE AP is public IP address of the IPsec server. Inside this tunnel, the following three separate data streams are present:
    - TR-069 towards ACS for configuration and notifications.
    - HTTP towards the File Server for SW image download and LTE AP log file upload.
    - MSL towards the MSL Broker for streaming KPIs.
  - **IPsec tunnel to EPC:** IPsec tunnel to EPC transports the S1 interface. The inner IP [source] address used by LTE AP for transmitting datagrams is allocated by IKE function of SecGW of EPC.
  - **IPsec tunnel to neighbor LTE APs:** IPsec tunnels to neighbor LTE APs (in the same venue), transporting the X2 interface. The inner IP [source] address used by LTE AP for transmitting datagrams is the one allocated by IKE function of SecGW of EPC.
    - X2 interfaces use tunnel mode. LTE APs outer IP address of X2 tunnel is the local address and is routable within LAN.
    - LTE APs discover their neighbors' inner IP address via S1AP interface.

Factory Defaults

All units when shipped include a base image that allows LTE AP to:

- communicate with sc-registrar.rucksuwireless.com that implements i-HeMS functionality and TR-069 protocol. LTE AP will receive its s-SecGW and s-HeMS FQDNs from SC Registrar. LTE AP is capable of mutually authenticating with SC Registrar.
- includes two X.509v3 client certificates (primary and backup) issued by Ruckus CA as its manufactured identity. These client certificates are referred as manufacturing certificate(s). The manufacturing certificate contains serial number of LTE AP and URL of OCSP server that can supply revocation information.
- includes root CA certificate of all the trusted CA and Ruckus CA Root certificates in its read-only secure file system. LTE AP uses root CA certificate to validate IPsec server certificate.

When LTE APs connect to cloud based ACS, they request to download the primary firmware image (LTE radio firmware) and to reboot while setting the new image as primary.

Reset button on LTE AP must be long pressed for at least 6 secs to cause a factory reset. Factory reset clears (removes) all the configurations on LTE AP and causes LTE AP to reboot and sets its factory image as primary.

NOTE

- Time duration of 6 secs is the same value as used on Ruckus' WI-FI APs.
- Factory firmware image does not include radio functionality i.e., LTE AP must update to a latest firmware to be able to transmit.

Feature introduced in 3.0

MOCN Configuration Support

MOCN configuration support from CLI is now available on Ruckus LTE AP SC 3.0.

QCI to DSCP Mapping

Ruckus LTE AP SC 3.0 provides support for QCI to DSCP mapping.

64 UE support

Ruckus LTE AP SC 3.0 provides 64 UE support.

Auto Log Capture

Auto Log upload configuration support from CLI is now available on Ruckus LTE AP SC 3.0. The logs shall get uploaded to the locally configured file server whenever this feature is enabled.

Macro Handover Support

Configuration support from CLI is now available on Ruckus LTE AP SC 3.0 for supporting Macro Handovers.

Software Compatibility Matrix

Software compatibility matrix support is now available on Ruckus LTE AP SC 3.0. An incompatible release shall be rejected during the upgrade if it fails to meet the software compatibility checks specified by the matrix.

Feature introduced in SC 2.4.1

Single Step Registration

Ruckus LTE AP installations require the installation data to be certified by CPI. Ruckus LTE AP Management provides the interface for CPI certification of LTE AP installation data. Single step registration enables LTE AP Management (without interfacing with SAS) to pass the CPI certified LTE AP installation data through LTE AP to SAS.

Feature introduced in SC 2.4

TDD Configuration 2

TDD Configuration 2 (Beta*) is now available on Ruckus LTE AP SC 02.04.00.0023 for LTE APs capable of operating in CA mode (P01-Q710/Q910-US02).

NOTE

*Beta = The feature is still under test, some anomalies may be observed.

Features introduced in SC 2.3.1

Channel-based Power Selection

With Release 2.3.1, Ruckus LTE AP calculates power based on the selected channel, bandwidth, and board type. Channel-based power selection ensures reduction in emission power at edge frequency. LTE AP will transmit lesser power at edge frequency of CBRS range with respect to center frequencies.

Ruckus LTE AP uses the following values for maximum power depending on the type of board and spectrum bandwidth being used.

Ruckus LTE AP		**Power**
Single Carrier (10 MHz)		22 dBm
Single Carrier (20 MHz)		23 dBm
CA SDL - PCell and SCell both 20 MHz		
Q710		22 dBm
Q910	Any carrier at edge channels i.e. 3560 MHz or 3690 MHz.	22 dBm
	Any carrier at 10 MHz from edge channels i.e. 3570 MHz or 3680 MHz and other carrier is not at edge.	22.5 dBm
	Any carrier at 20 MHz from edge channels i.e. 3580 MHz or 3670 MHz and other is not at the edge or within 10 MHz from edge.	23.5 dBm
	Carriers at channels other than the above.	24 dBm

Certificate Upgrades

Ruckus LTE AP supports ARRIS PKI and WINNFORUM PKI certificates. Two device entity certificates are generated (two for each PKI) corresponding to the two key-pairs specific to each LTE AP. For ARRIS PKI as well as WINNFORUM PKI, there is a dedicated root CA certificate and intermediate CA certificate. Thus, the following certificates are present on an LTE AP supporting ARRIS PKI and WINNFORUM PKI certificates:

ARRIS PKI	• Two ARRIS PKI device entity certificates from ARRIS PKI associated with the LTE AP serial number suffixed with indices 1 and 2 (corresponding to the two certificates generated - one each per key-pair). • ARRIS PKI Root CA certificate • ARRIS PKI Intermediate CA certificate
WINNFORUM PKI	• Two WINNFORUM PKI device entity certificates from WINNFORUM PKI associated with the LTE AP serial number suffixed with indices 1 and 2 (corresponding to the two certificates generated - one each per key-pair). • WINNFORUM PKI Root CA certificate • WINNFORUM PKI Intermediate CA certificate

Feature introduced in SC 2.3

Support for Venue Profiles

With Release 2.3, support for Venue profiles on Ruckus Cloud Management is available.

Features introduced in SC 2.2

Carrier Aggregation

Carrier Aggregation (CA) is an LTE Advanced feature that provides an increased bandwidth and throughput to an LTE CA-capable UE in downlink (DL) mode only. The feature is enabled on CA-capable UE (CAT 6 onwards).

In a CA cell, carrier-1 is termed as primary serving cell (PCell) and carrier-2 is termed as secondary serving cell (SCell). In CA-SDL configuration, LTE AP aggregates only SCell-DL along with PCell-DL and uses it for DL transmission to a CA-capable UE.

LTE AP has a single S1 and X2 interface in CA-SDL case and PCell is responsible for controlling data delivery over SI and X2 interface, i.e. there is no interface existing between SCell and EPC or SCell and neighbor AP. LTE AP has same UL/DL TDD configuration for both PCell and SCell.

In current scope, the following bandwidth combinations are supported.

- For CA-SDL configuration,
  - 20+20 MHz
- For non-CA cells,
  - 20 MHz
  - 10 MHz

Unless two or more than two 20 MHz channels are available, PCell alone will be set up.

FQDN support for MME

Ruckus LTE AP accepts Mobility Management Entity (MME) information in Fully Qualified Domain Name (FQDN) format.

Features introduced in SC 2.1

Alarm Enhancements

In Ruckus LTE Release SC 2.1, some alarms were refined to indicate appropriate AP condition.

Software Download on Low Bandwidth

Release SC 2.1 supports low throughput internet connection for downloading the software package. LTE AP estimates download throughput and in case of low internet speed, AP retries firmware download to accommodate low speed.

Auto-EARFCN

Release SC 2.1 supports Auto-E-UTRAN Absolute Radio Frequency Channel Number (EARFCN) feature that enables Ruckus LTE AP to auto-detect inter-frequency carriers (NL Scan based), add inter-frequency neighbors, and transmit SIB 5 depending on Spectrum Inquiry.

Once a neighbor is no longer detected, it is deleted after a pre-set timer.

LLDP Based PoE Power Negotiation

Ruckus LTE APs & ICX switches are capable of negotiating power using Link Layer Discovery Protocol (LLDP). LLDP is a layer 2 network discovery protocol that enables a station to advertise its capabilities to and to discover other LLDP-enabled stations in the same 802 LAN segments. LTE AP informs its capabilities and negotiates power requirements with a switch using LLDP messages. Based on power requirements for operation, LTE AP is classified under Class 4 Power class.

If power negotiation results in Power class less than 4, LTE AP raises an alarm indicating power negotiation failure.

IPv6 inside IPv4

Release SC 2.1 supports IPv4 address/FQDN for Evolved Packet Core (EPC) SecGW. EPC SecGW allocates IP address to the tunnel established by LTE AP that can either be IPv4 or IPv6 address. LTE AP accepts either IPv4 or IPv6 address allocations for the inner tunnel IP for EPC interface.

IPv4 opt 124/125 and Vendor Extensions

In Release SC 2.1, LTE AP sends the vendor class option 60 to IPv4-based DHCP server in the enterprise. It sends "ARRIS" as the vendor class.

64 UEs Support

Release SC 2.1 supports 64 Radio Resource Control (RRC) connected User Equipments (UEs) simultaneously. Data transfer can be done on 64 UEs at the same time.

Features Introduced in SC 2.0.2

GPB Enhancements for GPBS

In Release SC 2.0.2, enhancements have been made to identify LTE APs that can detect GPS satellites and report related KPIs.

QC 7.7 Integration

QualComm 7.7 version is integrated with Release SC 2.0.2.

Ruckus Q410 LTE Access Point

Q410 is an indoor LTE AP supporting B48 LTE band (CBRS 3.55 - 3.7 GHz) with Network Listen feature. Q410 improves mobile coverage and capacity inside buildings. Q410 utilizes shared spectrum on CBRS band and enables venues to deploy an LTE network with the simplicity of Wi-Fi.
Q410 contains WGR7640 GPS receiver from Qualcomm for synchronization and timing purposes.

Alarms and Events

With release SC 2.0.2, LTE AP sends the total number of UEs in use to Ruckus Cloud. Ruckus Cloud displays these numbers on its user interface.

Features Introduced in SC 2.0.1 and Earlier Versions

Features in SC 2.0.1 and Earlier

LTE AP SC 2.0.1 and earlier are versions that enabled LTE AP to become operational.

These versions include the following basic features.

- LTE AP Management connection.
- Accurate LED display to reflect AP connectivity status.
- Deployment of new LTE AP unit without user intervention.
- New firmware download on all LTE APs in a venue without rebooting LTE AP.
- Reporting of alarms/events to LTE AP Management for faults/events triggered on LTE AP.
- Streaming real-time KPI statistics to LTE AP Management.
- Certain configuration changes to LTE AP without reboot.
- RucKPI (a GUI interface) to view KPI statistics of all LTE APs across a venue.
- LTE AP supports Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) duplex mode.
- LTE AP supports 10 MHz and 20 MHz bandwidth configuration depending on the bandwidth allocated by SAS.
- Inter-frequency and intra-frequency handovers based on X2 and S1 interface.
- Band 48 support that can operate within the entire Citizen Broadband Radio Service (CBRS) frequency range (3550-3700) using bandwidth of 10 MHz or 20 MHz.
- ChannelFly (LTE SON feature) which enables LTE AP operation with minimal interruption.
- SAS TS V1.1 compliant including signaling protocol and procedures for SAS-LTE AP interface.
- IP allocation for LTE AP units using Dynamic Host Configuration Protocol (DHCP) server.
- Use of 0 to 3 VLANs inclusive.
- IP Security (IPSec) connection with LTE AP Management and EPC SecGW.
- LTE AP supports TrustZone that provides Trusted Execution environment for LTE AP operation.
- Use of certificate-based mutual authentication and IP Security when connecting to another LTE AP over X2 interface.
- Multi-Public Key Infrastructure (PKI) support and supports CMPv2 procedures for enrollment to CBRS PKI and EPC SecGW.
- Timing and sync via Precision Timing Protocol (PTP).
- GPS/AGPS synchronization management with GNSS as the primary sync source.
- Bonjour support that is used for local discovery of LTE AP whenever LTE AP is disconnected from LTE AP Management.
- Upload/Download Diagnostic feature provides support to check the statistics of uploading/downloading file/data on/from the server.

SON Overview

About SON

Self-Optimizing Network (SON) optimizes newly deployed Access Point (AP) performance by automatic procedures. After initializing APs with a basic configuration, SON uses environment measurements to auto tune the network continuously to improve performance.

SON configuration for each AP is computed internally within the AP and is synchronized with other installed APs and eNBs in the environment.

Ruckus LTE AP deploys the following SON functions:

- PCI selection, conflict detection, and resolution
- Network Listen
- Automatic Neighbor Relation
- RACH Parameter Optimization
- ChannelFly
- Secure X2
- Transmitted Power Management
- Auto-EARFCN

PCI Selection, Conflict Detection, and Resolution

The main objective of PCI selection, conflict detection, and resolution feature is to select a PCI value that does not collide with neighboring cells. LTE AP operates with the provisioned set of PCIs with minimum or no intervention from the operator.

PCI selection function selects a PCI for LTE cell at power-up. During its operation, an AP can reselect a new value if PCI collision or confusion is encountered. PCI selection module also consists of PCI collision, confusion detection, and resolution functions that are needed in a dense LTE AP deployment. PCI collision and confusion occur with intra-frequency neighbor.

In Carrier Aggregation (CA) mode of operation for LTE AP, PCell and SCell - each have access to the same pool of PCIs based on the range defined in Network configuration. SON ensures that each cell selects a PCI after excluding PCIs of the co-channel neighbors.

NOTE

- Both PCell and SCell PCI selection is independent of each other and an AP may have both cells operating using same PCI. However, PCell and SCell always operate on seperate channels/frequencies without causing any issues.
- In X2 messages (X2 Setup and X2 LTE AP configuration update), cell information for both PCell and SCell (if operational with an authorized grant) is exchanged as served cell information. eNB-Id is (28-bit) derived from ECI of PCell. However, other X2 messages (Load Information and Resource Status) contain information of PCell only. Transmissed Power Management (TPM) related X2 message contains PCell and SCell information (if SCell is operational).

As per 3GPP specifications, range of phyCellId is 0..503.

Triggers and Resolution for PCI Collision

Following illustrations show the triggers and resolution for PCI collision.

FIGURE 3 Power-up

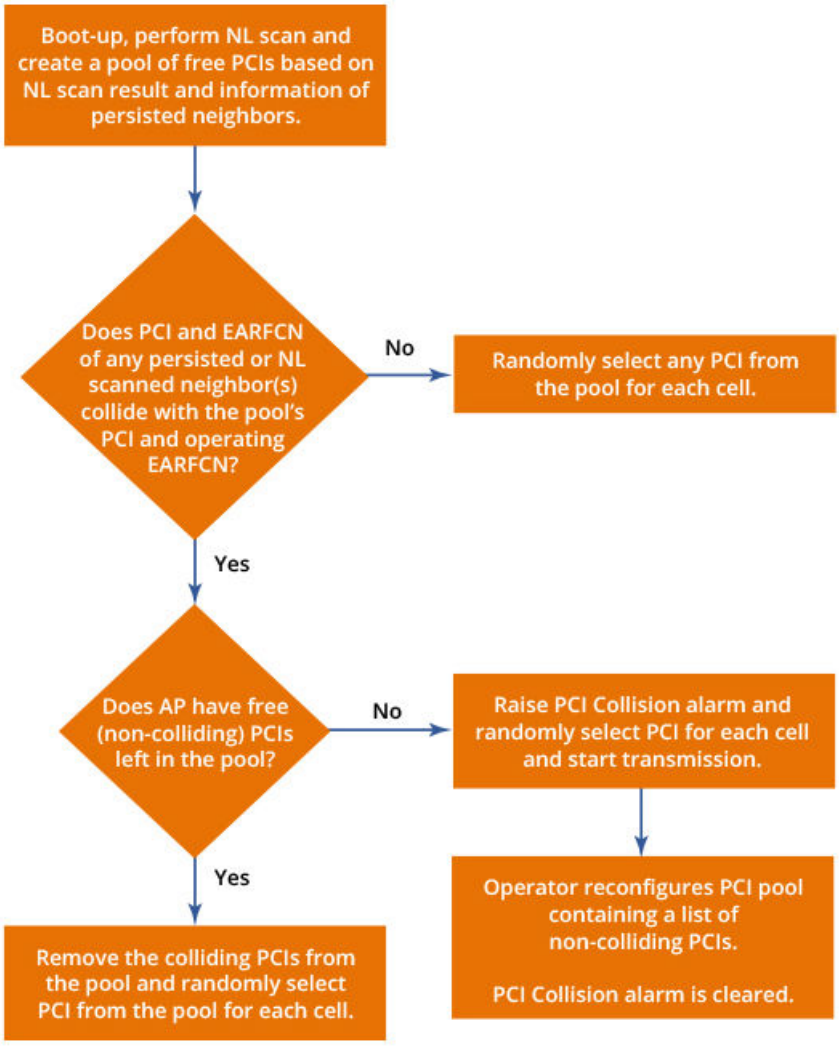


FIGURE 4 Run-time (Periodic NL)

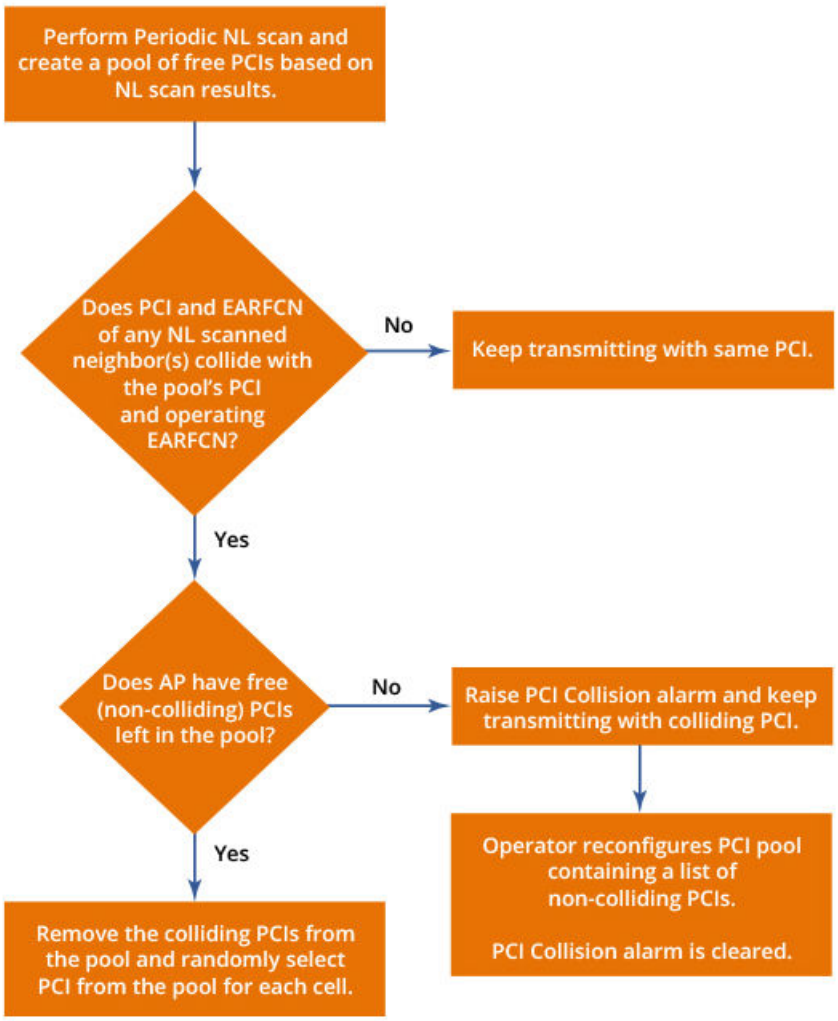
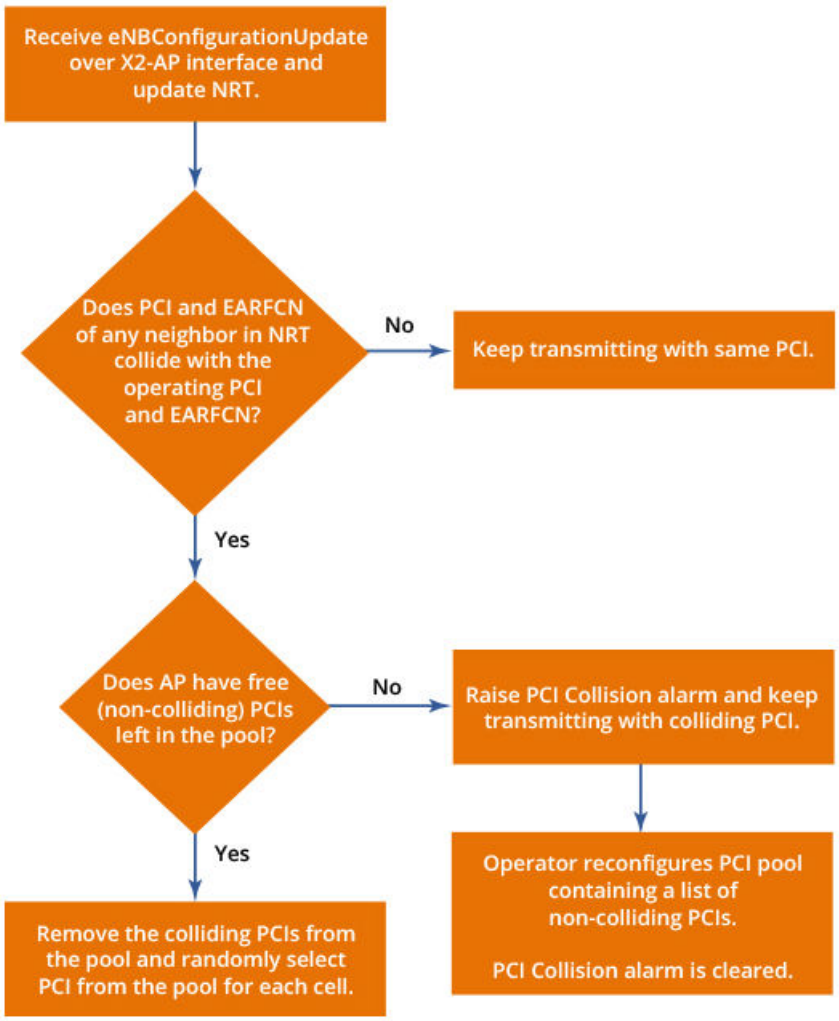
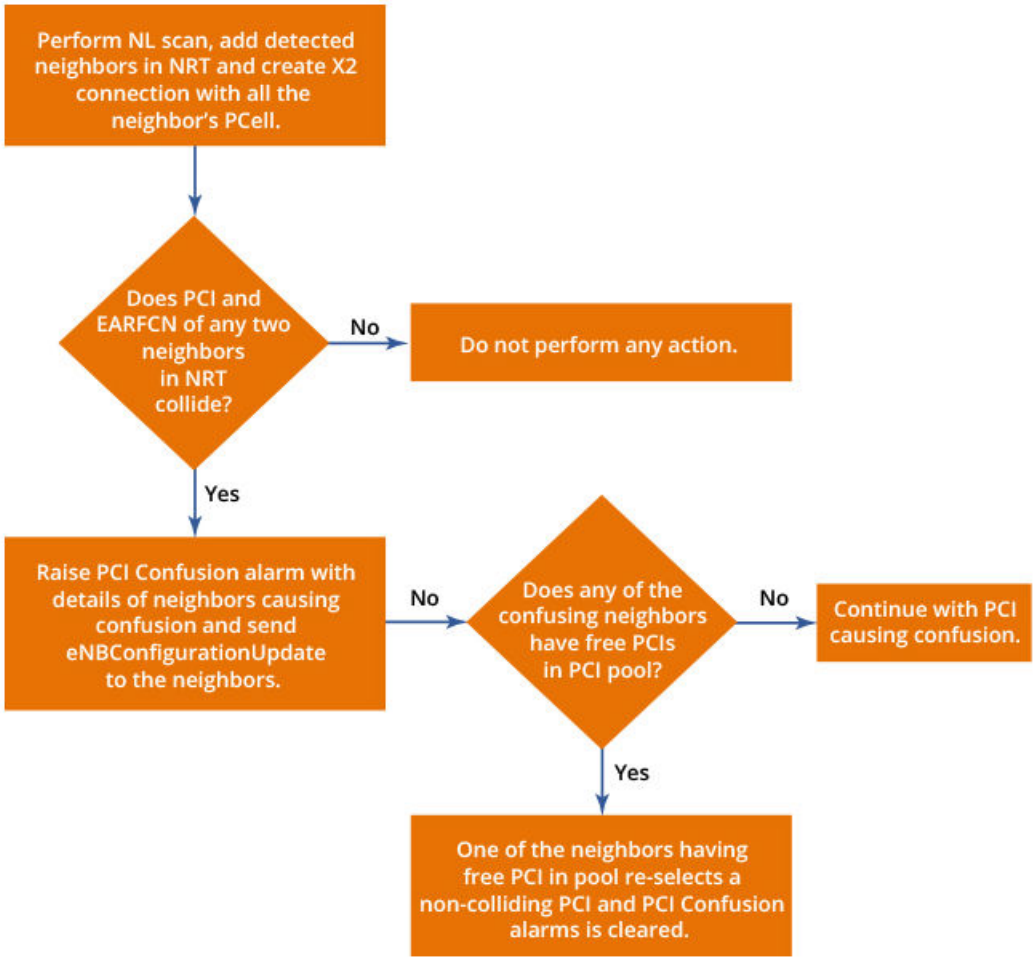


FIGURE 5 Run-time (neighbor information update received over X2)



Triggers and Resolution for PCI Confusion (for both start-up and run-time)

Following illustration shows triggers and resolution for PCI confusion.



There can be cases where NRT of an AP gets updated due to CGI information of neighbor received through UE instead of NL. In such cases, the run-time procedure depicted above is followed.

Network Listen

LTE AP is capable of network listen (NL) on Band 48. The results from network scan are provided to SAS as part of measurement reports as directed by SAS and also used for PCI Selection/Reselection, ANR, and Channel Selection/Reselection (Channel Fly) SON functions. LTE AP performs NL at power-up with no grant available and also performs NL periodically while transmitting on the authorized grant from SAS. Since the intra-band NL during cell transmission can impact cell operation and consequently performance/throughput, the periodicity of NL needs to be set appropriately. For Channel Selection/Fly and measurement reporting to SAS, NL measurements are restricted to RSSI measurements over the entire Band 48.

Following are the triggers for NL.

- **Boot-up NL:** This is performed on all channels of Band 48 based on carrier bandwidth.
- **Periodic NL:** This is performed periodically every 1800 seconds.

ANR

Automatic Neighbor Relation (ANR) is for automatic creation and maintenance of Neighbor Relation Table (NRT) for neighbor LTE cells. ANR facilitates efficient neighbor relationship management and enhances UE mobility.

ANR can be established using below methods:

- **Network Listen:** APs scan each other for SIB1 acquisition and add the successfully scanned neighbor in NRT.
- **UE-based CGI acquisition:** AP sends a request to UE to acquire CGI information of the cells reported in measurement report through SIB1 acquisition.
- **X2-AP link establishment:** APs that establish X2-AP link add each other in their corresponding NRTs.
- Interfrequency ANR addition through auto-EARFCN.

Neighbor Detection Function (ANR component) detects new neighbors and adds these to NRT. ANR also contains the Neighbor Removal function to clean up outdated NRs from NRT.

An existing Neighbor Relation from a source cell to a target cell means that LTE AP controlling the source cell:

- knows Target Cell Identifier (TCI) of the target cell. For EUTRAN cells, TCI is the ECGI and PCI of the cell.
- has an entry in NRT for the source cell identifying the target cell.
- has attributes in NRT entry that are set to default values.

NRT is created per cell for each AP. In CA mode, NRT updated from X2 messages (X2 Setup and eNB Configuration update) includes both PCell and SCell reported by the neighbor AP. Also, LTE AP includes both PCell and SCell (if setup) related information as serving cell information in the X2 Setup and eNB config update messages to its neighbors.

Establishing X2 with newly detected neighbors or updating NRT to the neighbors with an X2 occurs as for single carrier case with an enhancement that both serving PCell and SCell and neighbor cells are included.

RACH Parameter Optimization

Random Access Channel (RACH) Optimization SON function applies to RACH on PCell only. RACH parameter optimization allows neighbor LTE APs to exchange information about their used PRACH resources (and thus avoid interference and RACH collisions).

RSI Selection

RSI selection feature selects a rootSequenceIndex (RSI) from provisioned set of RSIs automatically. The feature works closely with PCI selection. Once a PCI is selected, RSI is selected from a pre-provisioned RSI list. The following is a list of functions and requirements for SON RSI selection:

- RSI selection is triggered after PCI selection.
- If PCI selection fails, RSI selection also returns failure.

Defined range of rootSequenceIndex is 0..837.

ChannelFly

ChannelFly consists of Channel selection and Channel switch.

Channel Selection

Spectrum Selection Module (SSM) performs initial channel selection based on NL measurements of the entire Band 48 and available channels received from SAS through Spectrum Inquiry procedure. It performs initial scan as well as periodic scan. Initial scan is performed on the entire band and the periodic scans are based on Spectrum Inquiry response. Channel selection computes PdB (penalty metric) of the channel and ranks based on lowest PdB. In a single cell carrier, only the best channel is selected and assigned to the first cell. With CA, after selecting the first channel, the second best channel is selected. If no additional channel is available, SCell will not be operational. SSM does not need to maintain the exact binding of the channel with cell index. However, to simplify the call flow with LTE AP, cell association is maintained.

Currently, bandwidth combinations 20+20, 20, and 10 MHz are supported. To operate in CA mode and setup the SCell, more than two 20 MHz channels are required.

Channel reselection can take place independently. Assigned channel with higher PdB is replaced with a better channel if one is available.

Any time during the operation, if any of the existing grants is either revoked or suspended, following cell specific operations are carried out:

- If SAS grant for the second cell is revoked, it is disabled after gracefully releasing SCell context of the existing UEs.
- If SAS grant for the primary cell is revoked, then the following actions occurs:
  - Secondary cell followed by Primary cell is disabled.
  - If a new authorized grant becomes available within the configured amount of time, then the same is used for PCell setup. After PCell setup, SCell is also setup.
  - Else, the existing grant assigned (with associated PCI) to the second cell is reassigned to primary cell and LTE AP continues to attempt acquiring a new authorized grant for SCell.

Channel Switch

Channel switch maintains individual cell contexts, one per cell. Cell context maintains cell specific information such as EARFCN, Channel bandwidth, RSTP, and its state machine. Each cell can be referenced by Cell index.

Channels set, Channel switch, and Channel suspend can be issued per cell.

Handling of Channel Set/Switch with new EARFCN

- Primary Cell
  - PCI reselection takes place for new EARFCN and SIB5 is updated.
  - SCell context of existing UEs is deactivated and released.
  - Existing UEs are either handed over or released.
  - Cell gets deleted and reconfigured with new EARFCN.
  - SIB4 and SIB5 are updated once cell becomes operational.
- Secondary Cell
  - PCI reselection takes place for new EARFCN.
  - SCell context of existing UEs is deactivated and released.
  - Cell gets deleted and reconfigured with new EARFCN.
  - SCell context gets added to the existing UEs by issuing RRCReconfigurationRequest with SCell Add/Mod parameters IE.

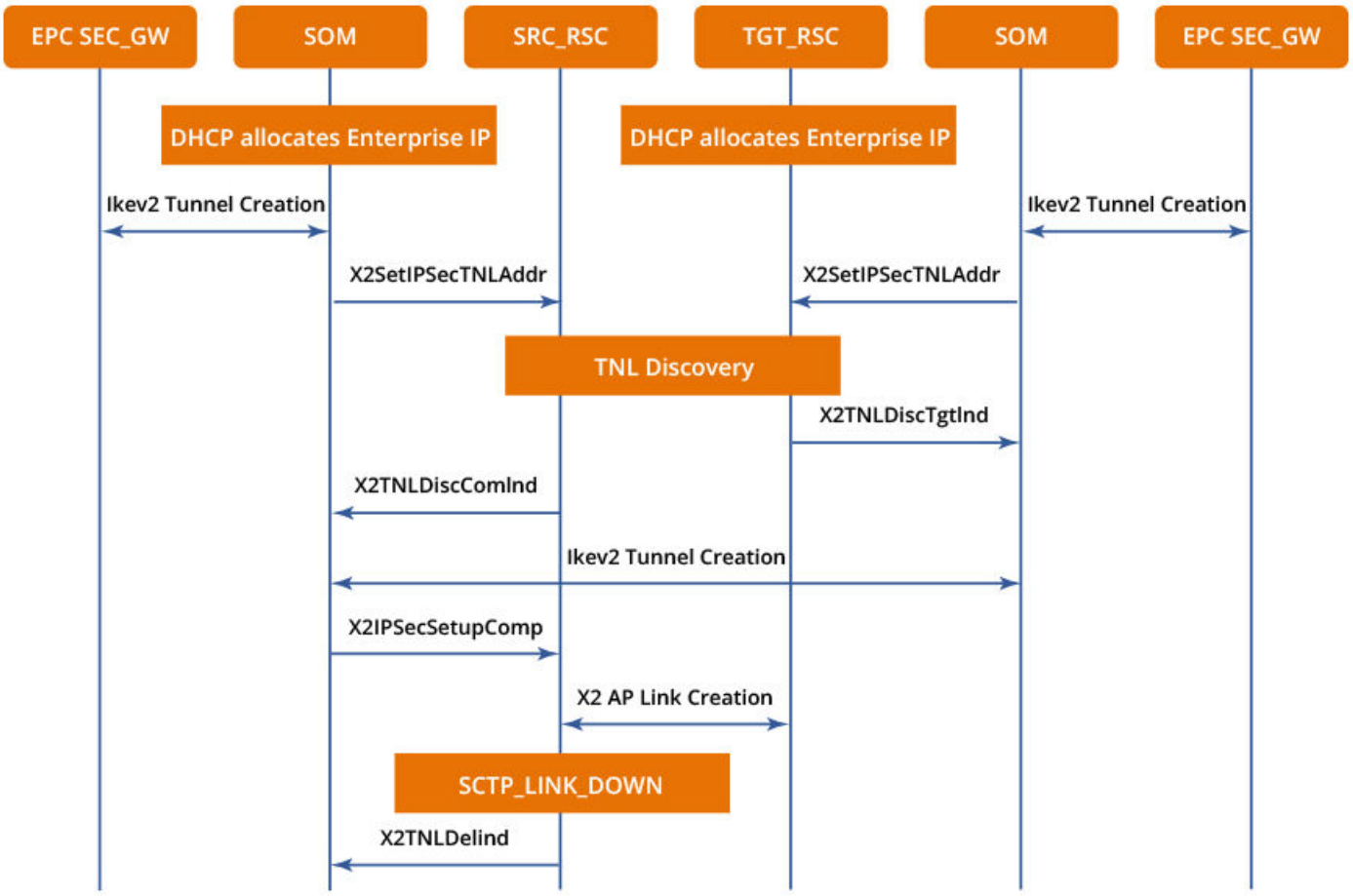
Handling of Channel Suspension

- Primary Cell
  - Cell block is issued.
  - Existing UEs are redirected to neighboring cells (Handover procedure).

  - After a timeout (35 sec), all sessions are forcefully released.
  - Cell is disabled.
- Secondary Cell
  - Active list of UEs with SCell is processed. For each UE, SCell gets deactivated and released.
  - Cell is disabled.

Secure X2

Ruckus LTE AP supports enterprise local X2 traffic routing over IPsec tunnels within the enterprise itself. LTE AP uses certificate based mutual authentication and IP Security when connecting to another LTE AP. Secure X2 is established using TNL discovery procedure. X2 connection is established between two PCells. SCell (if available on either AP) will not have any direct X2 relation with neighbor LTE AP. However, SCell information (PCI, ECI, TAC, PLMN-Id, and TDD Info included) will also be included in X2 Setup Request/Response and eNB Configuration messages to assist during PCI collision, confusion detection, and resolution. Any neighbor added in NRT through any mode, that is UE based CGI acquisition or NL, is considered for TNL discovery process. Secure X2 is established by creating Ikev2 tunnel between both the entities. After establishment of secure X2 connection, X2status for PCell is set to 3 (connected) and X2status for SCell is set to 4 (disconnected). Following figure is a schematic representation of TNL discovery followed by secure X2 connection.



Transmitted Power Management

In CBRS network, SAS tries to ensure that different CBRS Network operators (User-id) in an overlapping coverage area (WinnF defined "Connected set") are assigned different frequency channels. Also, use of single_frequency group-type (defined by WinnF) ensures that LTE APs belonging to the same User-id are assigned same channel in a connected set as far as possible. The above two tendencies, make the case for Ruckus LTE APs to perform Transmitted Power Management (TPM) strongly. In such deployments, TPM selects transmission power for an LTE AP based on RSRP received from the closest neighboring cell capped by the maximum transmission power capability of LTE AP. TPM also needs to consider that the calculated transmission power is such that the power provides a minimum coverage area for the cell to avoid cell shrinkage, which could lead to frequent and preemptive UE/session handovers (also known as ping-pong effect).

In CA mode, TPM maintains two independent cell contexts with an independent state machine. Core power adaptation algorithm remains same. Common NL cycles are used and single set of NL reports are processed by each cell for power adaptation. Power computation and adaptation for PCC and SCC takes place independently. This may result in PCell and SCell transmitting at different power levels. In such a scenario, LTE AP coverage is determined by the PCell transmission power.

TPM algorithm relies on X2 communication between neighboring cells. Private messages are used for exchanging power reports. To support CA, private message is extended to support power report for the second cell.

TPM identifies neighbor cells based on ECGI value present in NL reports. This is used to identify X2 session to be able to exchange communication. Since SCells in the network do not have direct X2 communication, ECGI of the first cell is derived from ECGI of SCell. Derived ECGI is used to identify X2 session if a session already exists, otherwise it is used to setup a new X2 session with the neighbor.

Requirement for TPM to be functional

For TPM to be functional, X2-ANR between cells is required.

Auto-EARFCN

SAS can allocate a list of different frequency channels to LTE AP in a spectrum inquiry response at different times. Auto EARFCN is introduced to facilitate the process of generation of inter-frequency carrier list. Under this process, SON performs periodic NL scan (every 30 minutes) on the channels received in spectrum inquiry response and adds the EARFCNs corresponding to the detected neighbors in inter-frequency list. This list is sent to UE in the form of measurement objects at the time of measurement configuration so that UE can utilize this list to perform inter-frequency measurements and perform handovers. An EARFCN is removed from the list if no neighbors are reported on that EARFCN during NL cycles for 7.5 hours.

Requirements for Auto-EARFCN to be functional

Following are the requirements for Auto-EARFCN to be functional.

- Channel database, which is currently derived from spectrum inquiry, is required to perform NL scan.
- At least one neighbor needs to be detected through NL on the scanned channel to add the corresponding channel to inter-frequency list.

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