RADISYS <*Feature Description – FWA IN NR- CBRS – Circle Gx* >
Release V0.1

Revision History

Version	Author	Date	Description
0.1	Ankur Sharma	12 2022	Feature Description – FWA CGx
0.2	Ankur Sharma	12 2022	Added existing facility of transport

Contents

1. About this Guide

Broadband speeds in compliance with the FCC's definition (i.e., 25 Mbps download, 3 Mbps upload) are now more technically feasible using fixed wireless networks. This document provides the solution Description for deployment of the CBRS for FWA designed for Circle Gx (a.k.a. CGx) model. Radisys (a.k.a. Rsys) is proposing a fixed wireless access (FWA onwards) to CGx which is seen as a way to provide the broadband coverage to underserve and/or no serve US community. These are the area where traditional MNOs are still not present. Geography and/or terrain is also not suitable for fiber. CGx prefers to reduce the high cost of deploying local wireless access to subscribers, as well as economically serving customers in suburban, rural and remote regions in homes, small businesses and educational institutions. This is the last and the only leg of the wireless networks which is provided on a cost shared among many. Using a fixed wireless access system not only reduces the cost to CGx by leveraging unlicensed spectrum like CBRS(GAA version is open spectrum) and by sharing the cost of the facilities down to the user (e.g., base stations on small tripod , combined RAN server etc.) and eliminating the need of cables directly to the subscriber premises, but also makes the provision of services to new subscribers faster and easier.

This version of the specification focuses on GAA requirements for CBSDs which is TDD configuration for NR-TDD CBSDs, GAA channelization and SAS-CBSD protocol extensions , FWA models with network architecture model & interfaces , call/signaling flow.

With the explosive growth of the Internet, FWA is discussed for "e-MBB" use case only , a necessity of the Internet is a major driving force for the CGx and Rsys. , Rsys & CGx believes fixed wireless connection may be a desirable solution if cable or fiber is not available or cost-effective. If adequate care in the design such that the network is not overloaded and uses spectrum capable of broadband speed, subscribers will enjoy a high-quality signal. Fixed wireless is particularly cost-effective in low-density rural areas where there are few homes and businesses per mile, and therefore the cost of building wired networks is often high.

This document outlines Radisys's proposed implementation of above feature request for the 5G ORAN in Standalone mode. The information provided in the present document is limited to an overview of listed Feature, explaining its purpose and the main lines of the system's behavior to execute the Feature.

The proposed FWA System installation should provide at least a 3-cells(sector), although 6 is preferred, per site.
Some consumers may wish to utilize an existing OSS/BSS system that will support billing and provisioning of each customer service offering but Radisys MUST develop such EMS solution to make ZTP/PNP and covering key requirements in FCAPS. Some requirements in RF/Protocols/EMS (API based) may come in different phases though. Our long-term development must be very focused in API based interfaces that can interface seamlessly and allow for flow through provisioning from the OSS/BSS.

Radisys offerings must include all pre-integrated /pre-configured packages which must include:

- CPE outdoor :Outdoor unit mounted on wall
- Antenna/O-RU (4T4R) , Sectorization/diversity/Large BW supporting (IBW-OBW=150 MHz continuous
- Tower-bottom Combined DU-CU (1RU /PNF/1CC CA for n48 based FWA . FWA with combo DU+CU at tower bottom
- EMS (API or web provisioning /ORAN interfaces for combo "O1" DU-CU/Co-located CPE management)
- new and wider QoS scheme for end-to-end network delivering IPv4/IPv6 services.
- All IP Core/Aggregation routing & power at each tower location or data center (based on deployment model

This document will cover detailed technical and cost analysis of fixed wireless broadband options to reach areas in Dallas and California county, which is unserved by broadband, defined as 25 Mbps download and 3 Mbps upload as minimum baseline as per FCC. We focused on using Citizens Broadband Radio Service (CBRS) in 5G , and other emerging, available spectrum and technologies that can deliver broadband performance. We have also captured the associated capital and operational costs. We offer a short introduction to fixed wireless network management through EMS , handling of CBRS spectrum (DP/SAS), fixed wireless network characteristics, and the major factors that impact cost.

This document will address the capital cost per location served varies based on the scale of the network . This is due to the cost of tower equipment, backhaul, and other fixed costs for the distribution network independent of the outdoor customer premises equipment (CPE) and installation. The distribution network includes the 5G RAN - & 5G core equipment (HW/SW/connectivity accessories , licenses fee) , backhaul and data center equipment, including antennas located on towers, poles, or other structures that distribute service to a CPE; the distribution cost per served premises ranges from $560 for to $975 per premises. The cost of the CPE and installation for each location are consistent in our proposal. The cost of a ***new tower*** would likely be between $55,000 and $100,000, depending on the terrain and height needed. Though first attempt will be a rooftop deployment wherever feasible. We assumed that backhaul is provided by fiber optic cabling where it already exists and microwave or 5GHz links otherwise; assumption is that 10 percent of the sites require an additional microwave or 5GHz hop. Capital costs also include engineering and design, RF path analysis, structural analysis, site acquisition, and permitting.

Radisys believes Operating costs also vary across the different terrain within counties based on the number of towers required and the number of locations predicted to be served by our analysis model, primarily the number of locations served.

2. References

- 3GPP TS 38.401: NG-RAN; Architecture description (R15.8.0 onwards)
- 3GPP TS 37.340: Multi-connectivity Stage 2
- 3GPP TS 23.501: System Architecture for the 5G System
- CBRSA-TS-2001, “CBRS Coexistence Technical Specifications V1.0.0”, 12 December 2017.
- CBRSA-TS-2001, “CBRS Coexistence Technical Specifications V2.0.0”, 6 January 2019.
- Signaling Protocols and Procedures for Citizens Broadband Radio Service (CBRS): Spectrum Access System (SAS) - Citizens Broadband Radio Service Device (CBSD) Interface Technical Specification - Document WINNF-TS-0016 Version V1.2.7 21 March 2022
- 3GPP TS 38.133, “Requirements for support of radio resource management (Release 15.3.0).”
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- Signaling Protocols and Procedures for Citizens Broadband Radio Service (CBRS): 23 Spectrum Access System (SAS) – Citizens Broadband Radio Service Device (CBSD) 24 Interface Technical Specification, WINNF-TS-0016, Version V1.1.0, 18 July 2017.
- Electronic Code of Federal Regulations, Title 47, Chapter I, Subchapter D, Part 96, http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=0076fe7586178336d9db4c5146da8797&mc=true&n=pt47.5.96&r=PART&ty=HTML
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- RFC-5246, “The Transport Layer Security (TLS) Protocol Version 1.2”, Dierks and Rescorla, August 2008.
- RFC-2818, “HTTP Over TLS”, Rescorla, May 2000.
- RFC-5280, “Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile”, Cooper, Santesson, Farrell, Boeyen, Housley & Polk, May 2008.
- WINNF-17-SSC-0002, “Signaling Protocols and Procedures for Citizens Broadband Radio Service (CBRS): WInnForum Recognized CBRS Air Interfaces and Measurements”.

3. Acronyms

- *CBRS-A:* CBRS Alliance
- *CBSD:* Citizens Broadband Radio Service Devices
- *CCG:* Common Channel Group
- *CFR:* Code of Federal Regulation
- *CPI:* Certified Professional Installer
- *CP:* Cyclic Prefix
- *CxG:* Coexistence Group
- *CxM:* Coexistence Manager
- *DP:* Domain Proxy

- *EIRP:* Effective Isotropic Radiated Power
- *FFS:* For Further Study
- *FS2:* Frame Structure 2 corresponding to LTE-TDD operation in 3GPP Band 48.
- *GAA:* General Authorized Access.
- *GNSS:* Global Navigation Satellite System
- *PAL:* Priority Access License
- *PPA:* PAL Protection Area
- *SAS:* Spectrum Access System
- *TLS:* Transport Layer Security

4. Definitions

- *Blacklist: A list of CBSDs that are to be denied service.*
- *CBRS band:* The 3550-3700 MHz Citizens Broadband Radio Service band.
- *CBSD Antenna:* The radiating element(s) of the CBSD. Each CBSD has one CBSD Antenna. Note that the CBSD's antenna may be instantiated with multiple physical antennas (e.g., an antenna array for MIMO operation), but those antennas must be transmitting one aggregate waveform collectively from a single geolocation, and with a total transmit power that conforms to all the CBSD's registration parameters and authorized transmit power levels provided by the SAS in its active Grants (e.g., maximum allowable EIRP).
- *CBSD Registration:* The procedure by which a CBSD indicates to a SAS its intention to operate. Successful registration implies a validation by the SAS that the CBSD has been FCC certified and confers on the CBSD the right to be authorized by the SAS to operate in accordance with a Grant. During the registration process, each CBSD provides a fixed location, unique identifiers (e.g., owner information, device information), Group membership, and radio-related capabilities. A successful registration procedure concludes with the SAS providing a unique identifier for that CBSD.
- *CBSD User:* The registered entity that has operational responsibility for the CBSD.
- *Channel*: the contiguous frequency range between lower and upper frequency limits.
- *Citizens Broadband Radio Service Device (CBSD)*: Fixed Stations, or networks of such stations, that operate on a Priority Access or General Authorized Access basis in the Citizens Broadband Radio Service consistent with Title 47 CFR Part 96 [9]. For CBSDs which comprise multiple nodes or networks of nodes, CBSD requirements apply to each node even if network management and communication with the SAS is accomplished via a single network interface.
- *CCG (Common Channel Group):* A group of CBSDs, that are part of the same ICG, requesting a common primary channel assignment.
- *Connected Set:* A set of CBSDs represented by the largest set of vertices of a graph created at the SAS or CxM, in which any two vertices of the set are connected to each other through at least one path in the graph.
- *CxG (Coexistence Group):* A group of CBSDs that abide by a common interference management policy which is used to coordinate their interference within the group.
- *CxM (Coexistence Manager):* A logical entity responsible for managing coexistence between GAA users within a CxG in coordination with SAS.
- *Domain Proxy (DP):* An entity engaging in communications with the SAS on behalf of multiple individual CBSDs or networks of CBSDs. The Domain Proxy can also provide a translational capability to interface legacy radio equipment in the 3650-3700 MHz band with a SAS to ensure compliance with Part 96 rules [9].
- *Grant:* The authorization provided by a SAS to a CBSD, subject to a Heartbeat exchange, to transmit using specified operating parameters. Grants are identified by a unique Grant identifier. Once issued, a Grant's operating parameters are never changed; if new or modified operating parameters are required, then a new Grant must be obtained. The Grant's operating parameters are maximum EIRP and Channel. A Grant can be in different states as will be explained in this FRS.
- *Group:* A collection of CBSDs which are provided a special, common form of management by the SAS. The nature of the special management is dependent on Group type.

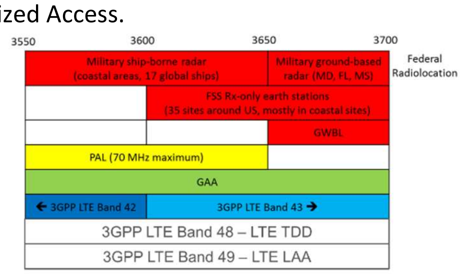
– *ICG (Interference Coordination Group):* A group of CBSDs belonging to the same CxG indicating that they can manage their own interference within the group, and do not need channel orthogonalization even if they have overlapping coverage.
– *PAL reserved channel:* A 10 MHz channel in the range of 3550-3650 that a SAS may establish for exclusive use of a set of one or more CBSDs that are registered as belonging to a PPA based upon acquired PAL rights.
– *PAL Protection Area (PPA):* An area within a PAL established by a PAL owner for protecting exclusive use of channels based upon the acquisition of PAL rights. The area is based upon the coverage area of the set of CBSDs that are members of the PPA. The SAS maintains a list of CBSDs that are members of the PPA.
– *REG-Conditional:* A parameter in the Registration-Request object that may be provided by the CBSD or may be provided through other means.
– *Spectrum Access System (SAS):* A system that authorizes and manages use of spectrum for the Citizens Broadband Radio Service in accordance with subpart F in [9].

5. Document Goal

The purpose of this document is to present the feature implementation of NR-CBRS as a baseline model which can be further customized to address multiple models. This guide will set the rules for the project once formally agreed to its content. The present document provides a summary of e2e NR-CBRS with required network elements.

6. CBRS overview

In 2015, the Commission adopted rules for shared commercial use of the 3550-3700 MHz band (3.5 GHz band). The Commission established the Citizens Broadband Radio Service (CBRS) and created a three-tiered access and authorization framework to accommodate shared federal and non-federal use of the band. Rules governing the Citizens Broadband Radio Service are found in Part 96 of the Commission's rules. Access and operations will be managed by an automated frequency coordinator, known as a Spectrum Access System (SAS). When managing spectrum access, SASs may incorporate information from an Environmental Sensing Capability (ESC), a sensor network that detects transmissions from Department of Defense radar systems and transmits that information to the SAS. Both SASs and ESCs must be approved by the Commission. SASs will coordinate operations between and among users in three tiers of authorization in the 3.5 GHz band: Incumbent Access, Priority Access, and General Authorized Access.



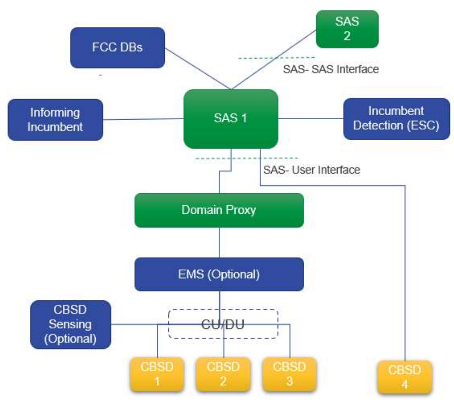
SAS Functions:

- Interaction with the ESCs:
  – Communicate with the ESC to obtain information about Incumbents transmission and instruct CBSDs to move to another frequency range or cease transmissions
- Interaction with the CBSDs:
  – Register and authenticate the identification information and location of CBSDs
  – Provide to CBSDs the permissible channels and max. transmission power at their location
  – Ensure that CBSDs operate in geographic areas and within the maximum power levels required
  – Protect PAL from interference caused by other PALs and GAA Users
  – Facilitate coordination between GAA users operating Category B CBSDs
  – Resolve conflicting uses of the band while maintaining a stable radio frequency environment.
  – Ensure secure and reliable transmission of information between the SAS and CBSDs
  – Protect GWBL until the end of the grandfather period
- Interaction with other SASs:

– Facilitate coordination and information exchange between SASs.

ESC Functions:

- An ESC is a spectrum sensor network that is able to quickly identify the presence of a radar signal
- Must monitor for incumbent radar activity in coastal areas and near inland military bases
- There are only ~20 total radars around the world, and each operates infrequently
- When incumbent activity is detected:
  - ESC communicates that information to a SAS
  - SAS notify the CBSD via the SAS/CBSD interface
  - CBSD must cease transmission 60 seconds after being notified to avoid interfering with incumbent radars

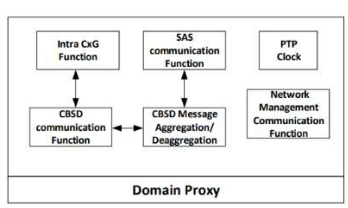


igure 1: CBRS Functional Architecture

7. CBRS Architecture

A high-level view as below shows the SAS-CBSD protocol interfaces, where:

- **CBSD**: Access Points are termed Citizens Broadband Radio Service Devices (CBSDs) in CBRS. CBSDs come in many types – fully integrated small-cells, distributed radio heads, or antenna clusters. CBRS defines a CBSD as a logical entity that radiates RF power, has antenna characteristics and is geolocated. CBSDs come in two classes, defined by their output power, and range. Category A devices must emit less than one watt of power per 10 MHz channel. Category B devices, typically used outdoors, may emit up to *50 watts per 10 MHz* channel. In an OnGo network, the 5G gNBs are connected to CBSDs, and are often in the same device. *The CBSD can have the ability to measure RF interference. This function is supposed to be optional however it is essential for GAA operation* – ***need to redefine.***
- **Domain Proxy** (DP): The DP is a logical entity that can represent one or more CBSD(s) to the SAS. The DP presents a consistent and secure interface to the SAS that can convey all messages pertaining to the SAS-CBSD interface for client CBSDs. We can assume this as a dynamic spectrum coordinator that implements the grant or lease information from the SAS and administers it to the CBSDs under its control. A DP as indicated ; communicates with the SAS on behalf of multiple individual CBSDs or networks of CBSDs The domain proxy is able to aggregate messages from several CBSDs to the SAS and can receive aggregated messages from the SAS to be distributed to CBSDs. A highlevel view of DP is below:



- **SAS**: All CBSDs must register with an FCC-certified Spectrum Access System (SAS) and obtain a channel grant from the SAS before transmitting in the CBRS band. To prevent interference with incumbent systems, the SAS allocates the spectrum to individual CBSDs and PAL license holders. To coordinate the CBRS band's usage, the SAS maintain a database of CBSDs and incumbent devices to calculate the aggregate interference. A new CBSD requests access to a range of frequencies from the SAS, and, based on the location of the CBSD, its category, and its antenna characteristics, the SAS grants access to one or more CBRS channels. When higher-priority users need channel access, the SAS can direct the CBSDs to reduce their output power, stop using currently allocated channels, or shut down entirely to avoid interference with PAL users or incumbent systems.

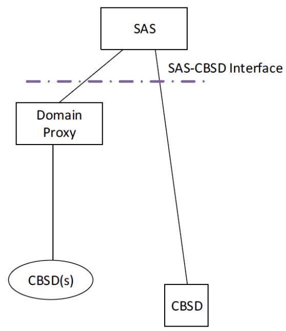


Figure 2: SAS-CBSD Protocol Interfaces

8. Fixed Wireless Network Deployment Cost Factors

There are many cost dependencies including what spectrum is available, how challenging the terrain is, how many locations are unserved17, how many existing towers there are, and the location of those towers. The challenge what Radisys sees that Dallas County may have many unserved locations but just a few tower's locations available. And some geography may have just a few unserved locations but the there are no towers close to those locations. FWA deployment costs depend on a range of factors including

- *Wireless equipment used*
  - which means RU/DU/CU/Data center/transport/5GC/*firewall/CG-NAT*, connectivity of ethernet and towards internet/ IP allocations (private/public)/ gateways and L2/L3 router/switches. Spectrum is unlicensed hence a minimal fee of $2.25 per cell , required capacity, and required coverage range for a solution defines what equipment will be required. Access point (tower) equipment costs for CBRS is relatively similar to a traditional 5G base station .Using 10 MHz of bandwidth, an access point can potentially support up to 32 to 64 locations for CBRS based on data requirement and RF conditions.
- *Design and Architecture feasibility*
  - Engineering and design costs include RF propagation studies, RF path analysis for point-to point connections, golden RF and network parameters , CPE management , SAS-EMS integrations , field and labs trial and further optimizations , structural analysis, construction plans, and permits. This cost is estimated to be 10 percent of the complete distribution network cost.
  - Estimates includes core network equipment for each solution to manage functions such as authentication, billing, security, and connection to the internet
- *Site Acquisitions and administrations*
  - Site acquisition costs include preliminary equipment dimensioning, power needs, shelter requirements, RF suitability, escorts, lease negotiations, and permitting. Actual costs will vary, but the average is approximately $25,000
- *Backhaul connection*.
  - This is the connection between two towers via a point-to-point wireless microwave or wireless backhaul link through 5GHz or a fiber connection between the wireless equipment on the tower and core network. If a wireless backhaul connection is required, equipment is estimated to cost close to $15,000. Fiber connection (leased fiber) costs vary per the length and data requirements

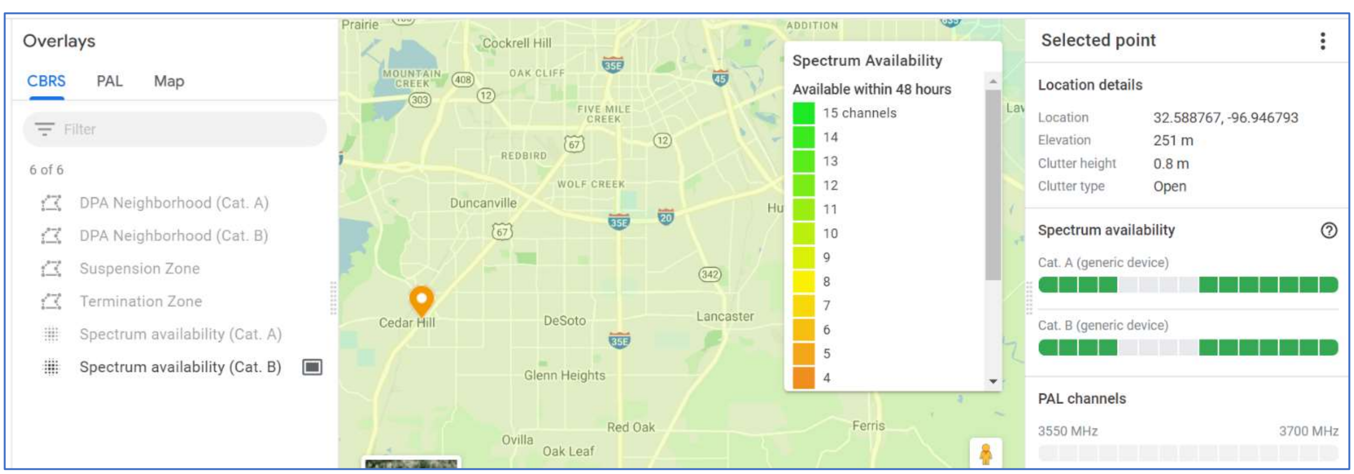
and latency constraint of fiber installed. CGx is planning to leverage all leased DF if available, there may be an ongoing lease cost to use the fiber to connect to the core.
*It is important to note that with CBRS the use of relays or repeaters is not allowed. CBSDs **cannot** utilize a mesh network using CBRS spectrum*

– *Placement on towers*.
  - FWA work best when the line of sight between tower and outdoor CPEs are optimized. Therefore, for such CPEs, space for best LoS/NLoS and near the top of a tower is most desirable, and therefore potentially more expensive. Cluttered and obstructions like trees/high buildings areas will require higher antenna placement and potentially the need for more robust towers instead of a pole. CGx is planning to use all government buildings and plan is to use either roof (tripod antenna) or wall mounted antennas as first approach.

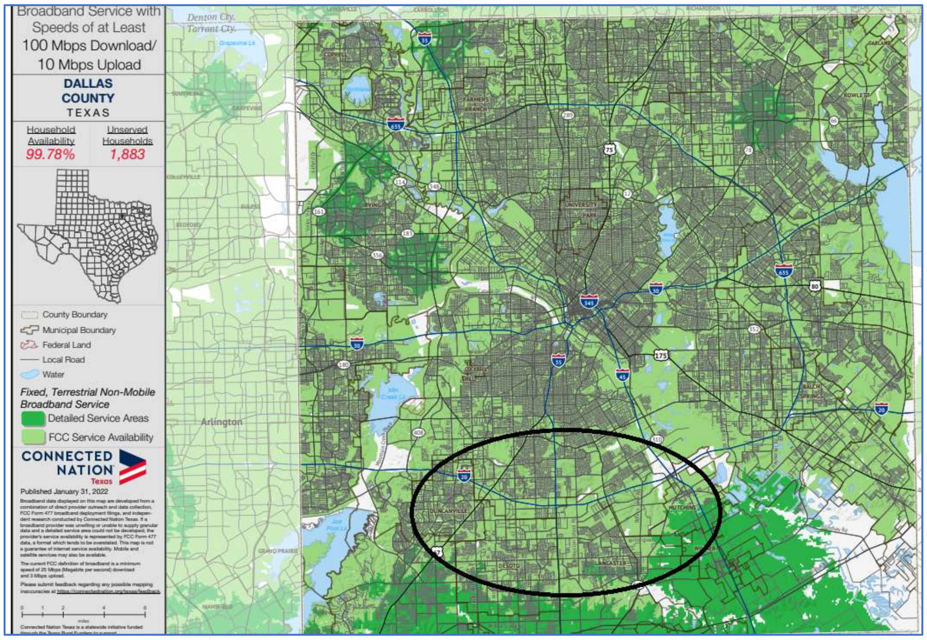
– *Future capacity and lifespan of investment*
  - Wireless equipment generally requires replacement after >10 years—exposure to the elements causes deterioration and technology continues to advance at a rapid pace, demand of capacity and coverage , new feature enhancements for spectrum efficiency improvement thus making older equipment obsolete. A network management cost for day-to-day optimization , alarm monitoring , HW failures , transport failures are the main cause which needs to be considered. ASW management and upgrade is other investments which service provider must consider.
  - We also considered staffing to operate the network including program and network management, network technician and technician training, help desk/customer service, portal/application/access management, general counsel, and some business administration roles for billing and other duties. Staffing requirements were scaled for each of the counties based on the number of estimated towers and users.

9. Spectrum availability

Radisys's analysis considers the use of GAA spectrum, that is readily available to CGx. CGx in each Dallas County will have access to the CBRS GAA spectrum, as available and coordinated by Google SAS. Although CBRS is more susceptible to clutter and terrain, but Radisys recommends targeted deployment with 5G enhanced features with CBRS GAA spectrum to increase capacity in areas where DF alone could not provide broadband service for all possible locations. Unlicensed 5 GHz spectrum is, by definition, available in all counties. However, it has inferior propagation characteristics relative to CBRS. Each block of FCC-controlled spectrum comes with its own set of technical characteristics, licensing processes, and eligible uses.
We estimate that, on average, 40 MHz of spectrum will be available in most of the below sub-urban & rural areas as shown below at Cedar Hill/Lancaster/DeSoto.



This project is strictly dedicated to serve the low-income community which are in a geography which just meets FCC base requirements of 25 mbps DL and 3 mbps UL as below:

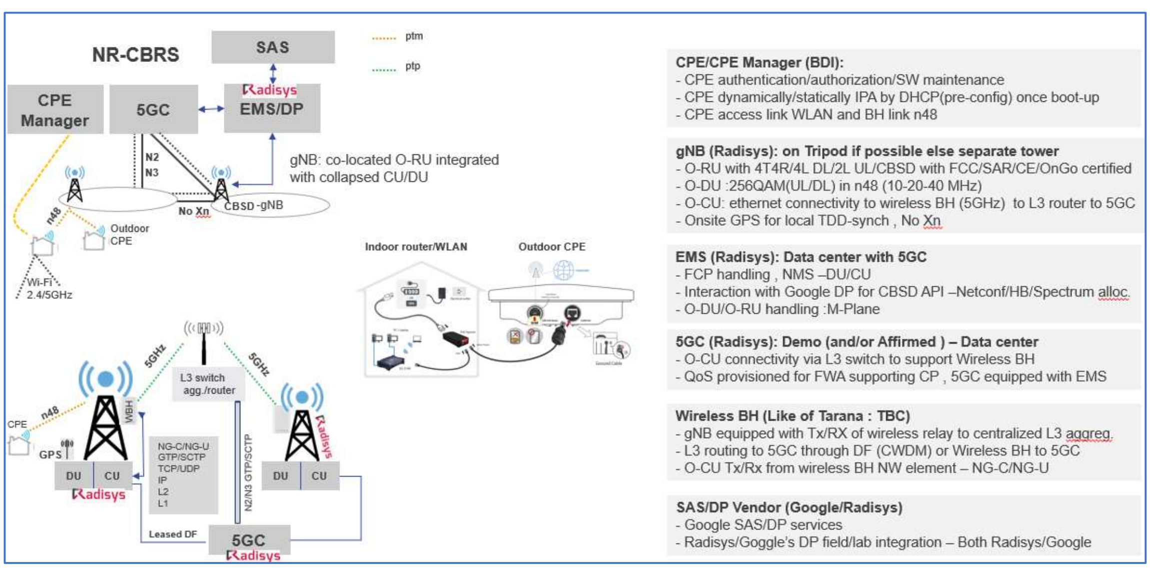


10. Network Architecture for Circle Gx with NR-CBRS

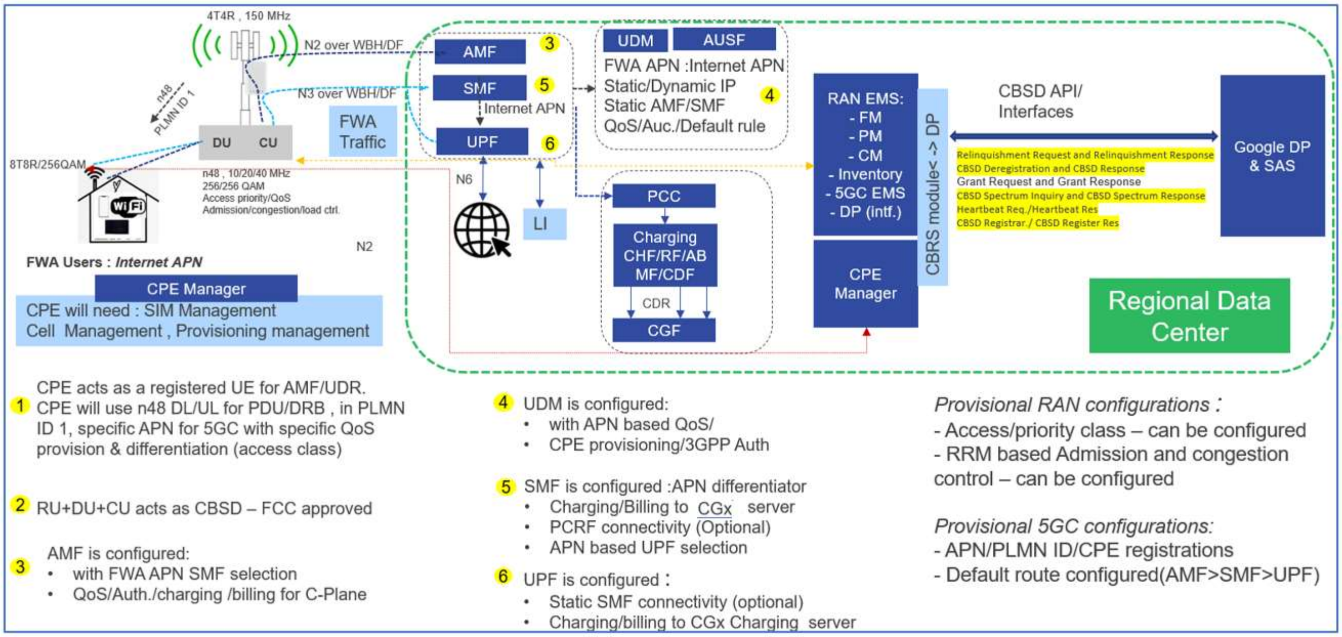
10.1. PNF gNBs and CBSDs

The CBSD (RU/DU/CU) is tied to the transmission point of the gNB – the antenna and the RRH (from Sunwave) will support n48 with 7.2x under transmission power requirement of FCC part 96 (EIRP=47dbM per 10 MHz). Radisys solution will have distributed functions/procedures like DU with numerology=1 , will get the ARFCN from EMS prior to bring the cell up . DU will wait for EMS to receive transmission power , Bandwidth and frequency channel number and transmit time expiry and will generate the cell config file with EARFCN/EIRP/BW/Tx expiry timer. Combo DU-CU will terminate to 5GC through leased DF and /or wireless BH or combo of both transports. But we do not anticipate any changes in CU.

High level view of network layout



For wireless access applications, the RAN as well as 5GC provides for radio subscriber management, subscriber paging and authentication, radio call delivery, radio resource allocation QoS enforcement , traffic handling , charging ,billing and LI. The detailed signaling flow for 3GPP based design is below:

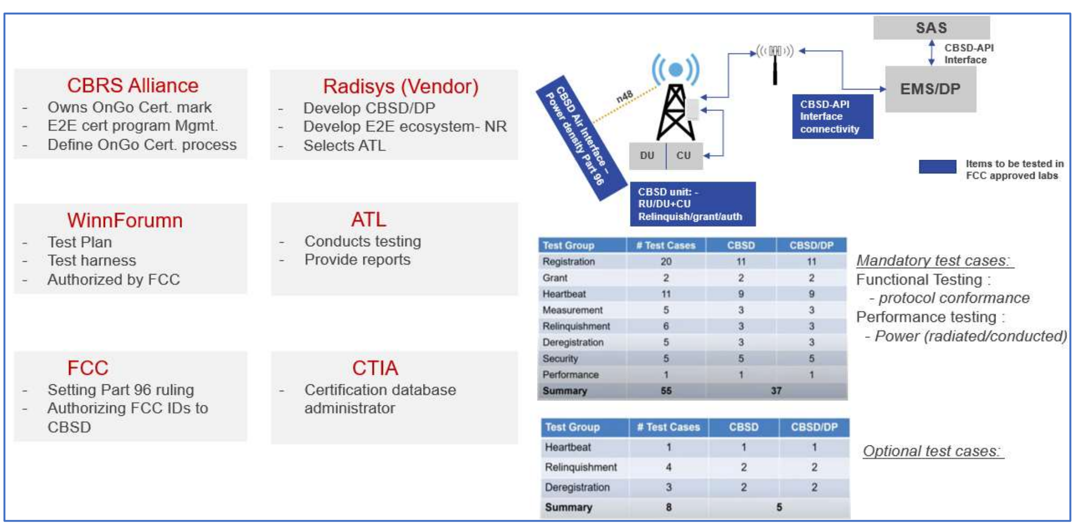


The test labs that are currently approved to act as independent Authorized Test Laboratories as part of the OnGo Certification Program. OnGo Certified devices are submitted to thorough testing by Element as a CBRS-authorized test laboratory. After successfully passing testing, the manufacturer is granted the use of the OnGo Certified mark, which certifies that a device has met strict requirements to ensure interoperability with other OnGo Certified equipment operating in the 3.5 GHz band.

In Radisys's offerings ,The EMS-OAM will manage the CBRS functionality on behalf of CBSD. Proposed EMS will have new CBRS module which will interact with Google SAS as listed in EMS enhancement sections.

SAS is planned with Google and for DP – Baicells/Combium and Telard network are still TBC.

Hence for final FCC certification , proposed CBSD will have ***RU-DU-CU-EMS*** as full ecosystem.



Test Group	# Test Cases	CBSD	CBSD/DP
Registration	20	11	11
Grant	2	2	2
Heartbeat	11	9	9
Measurement	5	3	3
Relinquishment	6	3	3
Deregistration	5	3	3
Security	5	5	5
Performance	1	1	1
Summary	55	37	

Test Group	# Test Cases	CBSD	CBSD/DP
Heartbeat	1	1	1
Relinquishment	4	2	2
Deregistration	3	2	2
Summary	8	5	

10.2. O-DU enhancements for CBRS

10.2.1. Channel Size

NR-CBRS is defined for full 150 mhz so can use a variety of channel sizes. For NR , it can operate in a channel as small as 10 MHz, and as large as 100 MHz. Channels are requested in 10 MHz intervals from the SAS, with a single PAL holder able to get 40 MHz of spectrum. We need to plan for channel size allocation of 10/20/40 MHz from SAS so O-DU must support these two channel sizes. DU shall support all channel sizes – 10/20/40 MHz.

10.2.2. Carrier aggregation -Phase2

Through use of carrier aggregation (CA), multiple channels, both within the CBRS band, can be combined to further increase bandwidth capacity. O-DU should not be limited in how much bandwidth they can use so support of Carrier Aggregation in bundling of channels of different BW and variable EARFCN is expected in phase 2. Please note that these channels can be contiguous or non-contiguous for maximum flexibility. While there is some additional overhead expected when CA is enabled (~ 15%) so peak throughput may not be exact same if we compare 10+10 CA vs 20 MHz contiguous.

10.2.3. Sub-Carrier Spacing

The 5G NR RAN, as an OFDM system, transmitters use multiple sub-carriers operating on a single channel. In band n48, these sub-carriers can operate with a sub-carrier *spacing of 30 kHz ONLY*.

10.2.4. Modulation

Higher modulation rates allow multiple bits to be sent simultaneously but are more susceptible to interference. For CGx , we will plan for *256QAM as for peak DL/UL* but will support all QPSK, 16QAM, 64QAM.

10.2.5. Layers

This represents the number of different beams being used to transmit data using MIMO techniques. More beams mean more data but are more prone to interference. The maximum is *4 in the downlink, and 2* in the uplink.

10.2.6. NR-TDD for NR-CBRS

OnGo networks use TDD, with the gNB and UEs using the same frequency channel but transmitting and receiving at specific times. In 5G, the network can dynamically shift between an uplink or downlink for allocating time slots to the DL/UL. But for DA/CGx , both , we propose and anticipate to at a minimum support allocating ~55% and ~75% to downlink *(10 of 18 and 14 of 18 slots with 30 kHz sub-carrier spacing*). And rest will be UL only.

For CGx , we anticipate planning for DL centric model : 75%DL & 25% UL

There are some literatures available who has anticipated the DL/UL throughput for NR-CBRS based on above:

Reference : (*https://5g-tools.com/5g-nr-throughputcalculator/)*

Peak Downlink Bandwidths [Mbps] by Channel Size

Channel Size [MHz]	Conditions	Modulation	Layers	30 kHz Sub-Carrier Spacing DL Bandwidth [Mbps] Max	75%	55%
10	Ideal	256 QAM	4	206	155	113
10	Moderate	256 QAM	2	102	77	56
10	Poor	64 QAM	1	38	29	21
20	Ideal	256 QAM	4	436	327	240
20	Moderate	256 QAM	2	218	164	120
20	Poor	64 QAM	1	82	62	45
40	Ideal	256 QAM	4	924	693	508
40	Moderate	256 QAM	2	462	347	254
40	Poor	64 QAM	1	174	131	96

Peak Downlink Bandwidths [Mbps] by Channel Size

Channel Size [MHz]	Conditions	Modulation	Layers	30 kHz Sub-Carrier Spacing UL Bandwidth [Mbps]		
				Max	25%	45%
10	Ideal	64 QAM	4	164	41	74
10	Moderate	16 QAM	2	54	14	24
10	Poor	2 QPSK	1	14	4	6
20	Ideal	64 QAM	4	364	91	164
20	Moderate	16 QAM	2	122	31	55
20	Poor	2 QPSK	1	30	8	14
40	Ideal	64 QAM	4	728	182	328
40	Moderate	16 QAM	2	242	61	109
40	Poor	2 QPSK	1	60	15	27

10.2.7. TDD Synchronization

CLI is very much expected even when CBSDs are operating on adjacent frequency channels. This interference can be of particular concern when the OnGo network is outdoors, using higher-power Category B CBSDs. Radisys plans to leverage the unicast model: CBSDs use the same TDD DL/UL patterns and synchronizing the timing between the CBSDs. Radisys O-DU will leverage using GPS or similar signals for a common timing reference, which is critical for proper functioning.

10.2.8. EMS interactions

DU needs to bring the cell up and for this "*Cellconfig*" IE needs EARFCN/BW/EIRP/Transmit expiry timer" . All these four parameters will be provided through EMS via O1 interface (Netconf) . DU must hold on to receive this IE and must not initiate any failure instead continuously monitoring the O1 interface. Radisys O-DU will follow subsequent steps to bring the NR-CBRS supporting O-RU.

10.2.9. O-DU requirements to support 8X8 CPE

FWA DURQ-1 - CAT-B O-RUs with 4X4 MIMO for NR.

FWA DURQ-2 -M-Plane profile as stated in section A.1 M-Plane IOT Profile – must have O1 to support CBRS parameters.

FWA DURQ-3 - LLS-C3 bridged connection) (G.8275.1 or PTP 1588 and GPS synchronization)

FWA DURQ-4 -n48's band support (3550-3700 MHz) , BW=10/20 /40 MHz as continuous spectrum anywhere within 150 MHz.

FWA DURQ-5 -Short NR PRACH preamble formats , dynamic PRB bundling , resource allocation for Power Headroom reporting capability , long and short C-DRX , timing alignment procedure for CPE's synchronization with gNB

FWA DURQ-6 -Downlink 256 QAM, Uplink 256QAM) for higher peak throughputs and for regular network coverage.

FWA DURQ-7 -Unicast scenario: same TDD Uplink: Downlink ratio is used across the region to avoid any interference between uplink and downlink between CPEs/sites.

FWA DURQ-8 -No CA planned for n48. Assumption is that Each sector should be engineered to provide at least 300mbps (assumes 40Mhz carriers) aggregate downstream capacity to CPE devices.

FWA DURQ-9 -Data inactivity monitoring.: based on "dataInactivityTimer": CPE transits to RRC_IDLE upon expiry of the timer). (TS 38.321). We must have user inactivity monitoring and informs its inactivity or (re)activation to CU-CP internally and data must be stopped to free up DU resources.

FWA DURQ-10 -Error correction through ARQ (only for AM data transfer) , RLC re-establishment , Max ARQ retransmission configuration for DL and UL , declare Radio Link Failure (RLF) when MAX ARQ Retransmissions expire at The DU Solution end.

FWA DURQ-11 -Ciphering/Deciphering , integrity protection/integrity verification , timer based PDCP SDU discard functionality so that we don't keep packets after 100 msec. in PDCP buffer , discarding the PDCP duplicate from CPE

FWA DURQ-12 -Standard 5QI support – we can start with static deployment of new 5G QoS (let's not limit to LTE 9QCI). We should have marked QoS flow ID in both DL and UL packets.

FWA DURQ-13 -Plan in phase 2 : support Extended cell radius- Format 0 for ~ 14 KM is prime

FWA DURQ-14 - O-DU must be capable in demultiplexing of SRS transmitted from multiple CPEs and correctly estimation of the uplink channel based on the SRS. Use this mechanism to estimates to channel RF conditions & add MIMO weights for multiple CPEs - (desirable in phase 1). At least 4-layer DL & 2L UL transmission shall be supported.
FWA DURQ-15 -DU must use support– Regular BSR, periodic BSR. BSR(Buffer Status report) Information of various candidate CPEs as well as their Channel Estimates (CSI) in deciding the final allocation of PRBs, etc.
FWA DURQ-16 - 5G-TDD cells should achieve cell phase synchronization using GPS or GNSS assistance , PTP. This cell phase synchronization accuracy at ≤ 3 µs for a wide area BS that has a cell radius ≤ 3 km. And beyond this limit, cell phase synchronization accuracy at ≤ 10 µs for a wide area BS that has a cell radius > 3 km.
FWA DURQ-18 -NR-NR TDD CA scenario shall maintain a common time frame reference for all bands and band combinations as per 3GPP specifications . Plan for phase 2
FWA DURQ-19 – DU must prepare cell config file when EMS shares the parameters like BW/EIRP/ARFCN/Transmit time expiry through O1 interface. DU must share the cell config file with CU and then bring the cell up.

10.2.10. O-CU architecture

To optimize the location of different RAN functions according to different scenarios and performance requirements, the gNB-CU will be in same server as of DU (collapsed F1 interface). No E1 interface planned. Standard N2/N3 interface needed.

Collapsed CU shall host the RRC ,PDCP protocol and the SDAP protocol of the gNB-CU. The gNB-CU terminates F1-U interface connected with the gNB-DU.

10.2.11. O-CU requirements

FWA CURQ-1 -RRC- NAS support to CPE for registration/authentication ,
FWA CURQ-2 -QoS Flow management and mapping to data radio bearers.
FWA CURQ-3 -Session management : user inactivity monitoring and informs its inactivity or (re)activation to and free resources
FWA CURQ-4 -Support CPE's RRC connected, RRC idle. Use dedicated RRC signaling for RRC connected CPE to transfer the information.
FWA CURQ-5 -Support configuration of AS security parameters for SRBs and DRBs for CPE.
FWA CURQ-6 -Broadcast barring control information associated with Access Categories and Access Identities as specified in TS 38.300
FWA CURQ-7 -Support RRC procedures for CPE as below:-

- RRC reconfiguration procedure to modify an RRC connection, e.g., to establish/modify/release RBs,
- Perform reconfiguration with sync, to Setup/modify/release measurements, to add/modify
- No mobility support in phase 1 but phase 2 will needed mobility as well
- RRC connection re-establishment fall back procedure. In this procedure The CU Solution shall initiate RRC set on receiving RRC re-establishment request. This will be needed if CPE initiated explicit/implicit detach.

FWA CURQ-8 -Unified access control procedure which is used to perform access barring check for an access attempt associated with a given Access Category.
FWA CURQ-9 -O-CU (RRM) support load-management triggers based on software-resources: user-count, call processing transactions, and this must be operator configurable events for various load thresholds. In such event, O-CU pushing CPEs to idle mode prior to idle-mode timer expiry in case of overload event (via RRC Release).
FWA CURQ-10 -Phase 1 interference mitigation via downlink transmits power allocation for NPDSCH/NPDCCH/Ref. signals
FWA CURQ-11 -When TDD-TDD NR-NR CA planned in phase 2 then we must target to support interference mitigation via cross carrier scheduling (coordinate the scheduling in different carriers to prevent interference)
FWA CURQ-12 -Support CSI reporting on per QFI and use these reporting for Interference measurements and then prioritize CPEs for DL allocations
FWA CURQ-13 -support QoS differentiation within a PDU session., Operator based QoS implementation enforced on CPE

FWA CURQ-14 -Prioritization based on admission control , load control : admission control based on PRB load ,interference and UL noise load and CPU, memory, storage utilization on hardware load.
FWA CURQ-15-Multiple APN/PDN support expected. DRB up to 4 are desirable because of multi clients in FWA for households.
FWA CURQ-16 - Frequency White/Backlisting
FWA CURQ-17 -**support preference for voice PDU session on mid- band. -like for voice centric UE vs e-MBB UE – TBC

10.2.12. 5G Outdoor CPE

A given 5G-RG (CPE) will ack like a UE towards gNB and will perform initial registration/ authentication/authorization. Commercially available CPE today supports “multi-PDN connections mode” and will act like in Bridge Mode: CPE will create multi-PDN connections for local clients. Thus, clients (Smartphones/PC/TV) request IP addresses from CPE, CPE will reply to an IP address got from one of PDN connections via gNB/5GC. The IP address of the first PDN connection is always allocated to the management of CPE. And going forwards, new IPA will be for data traffic.

After power on , CPE will do full band scan or “dedicated/pre-configured 5G-ARFCN” , PLMN/Cell selection (auto/manual mode) , APN/PDN request , and get IPv4/IPv6/Dual stack based on configurations. Behavior will be very similar like a traditional UE and must follow TS 24.501/24.502.

FWA CPE Management: A management system that provides remote access to the FWA CPE for configuration, performance measurement, or troubleshooting purposes. For FWA or fixed/mobile converged operators, this can be an integral part of EMS solution from Radisys. CPE management will be a separate entity and provided by CPE manufacturer. CPE manager will be integrated with EMS for notifications like authorization/authentication etc.
CPE Management Protocol, also called TR069 is a Broadband Forum technical specification entitled CPE WAN Management Protocol (CWMP). It defines an application layer protocol for remote management of end-user devices. It defines an application layer protocol for remote management of CPE devices. As a bidirectional SOAP/HTTP based protocol it can provides the communication between CPE and Auto Configuration Server (ACS). It includes both a safe configuration and the control of other CPE management functions within an integrated framework. Using TR-069 the terminals can get in contact with the Auto Configuration Servers (ACS) and establish the configuration automatically and let ACS configure CPE automatically. This can be supported by wireline or by service provider’s network. This may not be necessarily supported through 5G RAN-5GC during initial power up of CPE.
A CPE can be declared as faulty or barred through CPE management and can be declared OOS prior it starts 5G attach. In this model, it is expected that multi-function will be handled outside 3GPP based 5G ORAN like diagnostic tool (Ping, Traceroute, Download, Upload) , Monitoring (Ping, inactive/faulty devices, bandwidth consumption, latency, 5G, Wi-Fi security, and any other parameter available on a device (parameter-based monitoring), Download, Upload) , Alerting (Based on advanced monitoring extensions; ability to send alerts via e-mail , Security (HTTPS connector for devices and TLS for NBI) , any built-in services (CWMP, GUI, STUN and XMPP servers for NAT traversal).

10.2.13. CPE is from 3rd party with following requirements:

CPE RQ-1 - CPE(5G-RG) follows the 3GPP authentication procedure based on IMSI credential procedure documented in TS 23.501.
CPE RQ-2 - CPE must perform NW selection procedure with two main parts, PLMN selection and access network selection which is similar process like a normal UE cell selection and PLMN selection. The requirements for the PLMN selection are specified in TS 22.011 and the procedures are in TS 23.122. The access network selection part for the 3GPP access networks is specified in TS 38.300 for the NR.
CPE RQ-3 - The AMF/AUSF/UDM may authenticate/authorize the CPE during any procedure establishing a NAS signaling connection with CPE at CPE initial registration. The security architecture is specified in TS 33.501.
CPE RQ-4 -Power class 2: 26 dBm for n41/n77/n78/n79 , Power class 3: 23 dBm for all other FR1 (n48)
CPE RQ-5 -Built-in web server for web-based configuration

CPE RQ-6 Support DL 256QAM , 4x4 MIMO – 4L DL and 2L UL , DHCP allocation for static IPA to router/CPE, CA mode and 100MHz support , PoE
CPE RQ-7 Device Locking (Physical Cell Identifier (PCI)/Cell ID
CPE RQ-8 Tuning and locked in Absolute Radio Frequency Channel Number (ARFCN)/Frequency or by Band)

11. Additional RAN feature sets

11.1. Admission control

It is a (RRC) radio-resource-based admission control. We are dividing this feature sets in two different phases:
Phase 1: UE is camped on cell and requests setup of a radio resource control (RRC) connection , then CU/RRC must perform the UE admission procedure.
Phase 2: When UE requests an incoming handover, CU/RRC performs the user admission procedure.
So, in either case, we must have a common mechanism to perform this procedure. We recommend as below:-

11.1.1. CPU resource monitoring

The O-CU checks whether the CPU resource is limited or has available processing power. If the CPU resource is limited, the CU must reject the access request. How to validate the CPU within CU ?

- Flow control mechanism controls its own output data to new requests flow and reduces the data in-flows received from the peer NE (5GC/DU/CU). This means that CU will optimize (high or low) its own data rate or the data rate
- Low priority UEs will be denied once CPU utilization reaches to 80% of its capacity. Remaining capacity is reserved for mobility and urgent scenarios.

11.1.2. Based on licensed CPEs per CU

The O-CU checks whether the # of CPEs are limited. If the # of admitted CPEs have reached the maximum or the licensed user number, the O-CU determines that the # of CPEs are limited and the admission fails.

11.1.3. SRS monitoring

The CU checks whether the SRS resource is successfully allocated . To have better control for UL SRS allocations, we recommend adopting *user-specific periodic SRS resources* include user-specific SRS periods, user specific SRS bandwidths, SRS ports, and other resources.

O-CU must also adopt one of the following for FWA -CPE : –

- If the SRS resource is configured for the cell, the RRC supports uplink timing measurement using only the SRS. In case if the SRS resource allocation fails, the uplink timing of the UE may not be accurate and the RRC shall rejects the access request.
- If the SRS resource is not configured for the cell, the cell supports uplink timing measurement using the demodulation reference signal (DMRS). Even if the SRS resource is not allocated, the RRC accepts the access request.

11.1.4. Admission based on congestion

Four options may be triggered hence CU must consider the existing congestion status while allocating resources. The existing congestions is evaluated by checking the load status by monitoring the PRB usage and QoS satisfaction rate. For more details, we will cover the details in Congestion control section.

- UL congestion & no DL congestion
- DL congestion & no UL congestion
- DL congestion & UL congestion

When the cell is congested, the congestion control algorithm instructs the admission control algorithm to reject all access requests and, in addition, takes actions to reduce cell load

11.1.5. PRB monitoring at MAC

By monitoring the PRB usage of services with high scheduling priorities in the UL, O-CU shall learn about the usage of UL time-frequency resources in the cell and evaluates the cell load. In UL, services with high scheduling priorities- retransmissions,

SRBs, and SRs , so MAC must use the formula by calculating the above PRBs allocated divided by total # of PRBs available and then compare with defined threshold to judge if there is PRB utilization is reaching to 100%.
Parameters: Need to define a parameter to reflect as the threshold for deciding whether the uplink RB usage is high. This threshold is used in UL admission decisions. If the MAC layer reports that the uplink RB usage is greater than this parameter value, the uplink RB usage is regarded to be high and RRC shall act of this accordingly. We need to define high-low threshold so that MAC can reports when it is high and when it is low.

11.1.6. Preemption proposal

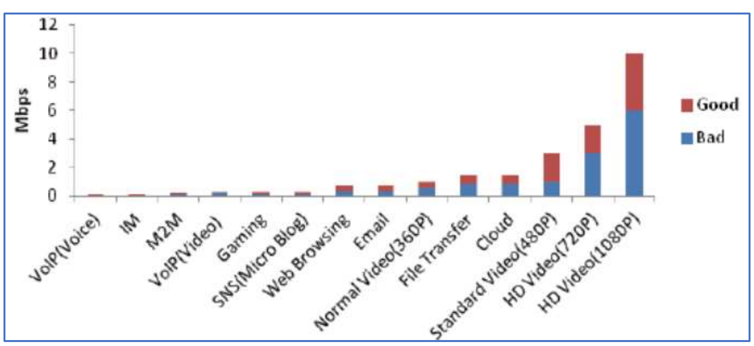
Preemption increases the access success rate for CPEs with high ARPs. However, users with low ARPs are forcibly released and their service drop rate increases. In FWA, we will have similar situations where CPEs will be discriminated based on their need and service plan. Some high priority CPEs over others. The way the O-CU may perform CPE-number-based preemption will increase the amount of signaling because of the following three actions:
- O-CU releases temporary RRC connections for those UEs/CPEs that eventually encounter preemption failures.
- O-CU releases RRC connections for preempted UEs/CPEs.

Parameters: We may choose to define as if RRC receives a new higher-priority services that could have failed to be admitted then RRC can preempt the admitted lower-priority services in the cell.
To implement, we should follow the LTE baseline , to indicate if a new service can preempt other services or can be preempted, NGAP_DRAB_SETUP_REQ message in the N2 interface. In this message for Non-GBR service , the value 1 (may-trigger-pre-emption) of the IE pre-emptionCapability indicates that the service can preempt other services and the value 1 (pre-emptable) of the IE pre-emptionVulnerability indicates that the service can be preempted. The value 0 indicates the opposite.

12. Capacity Planning and initial optimization

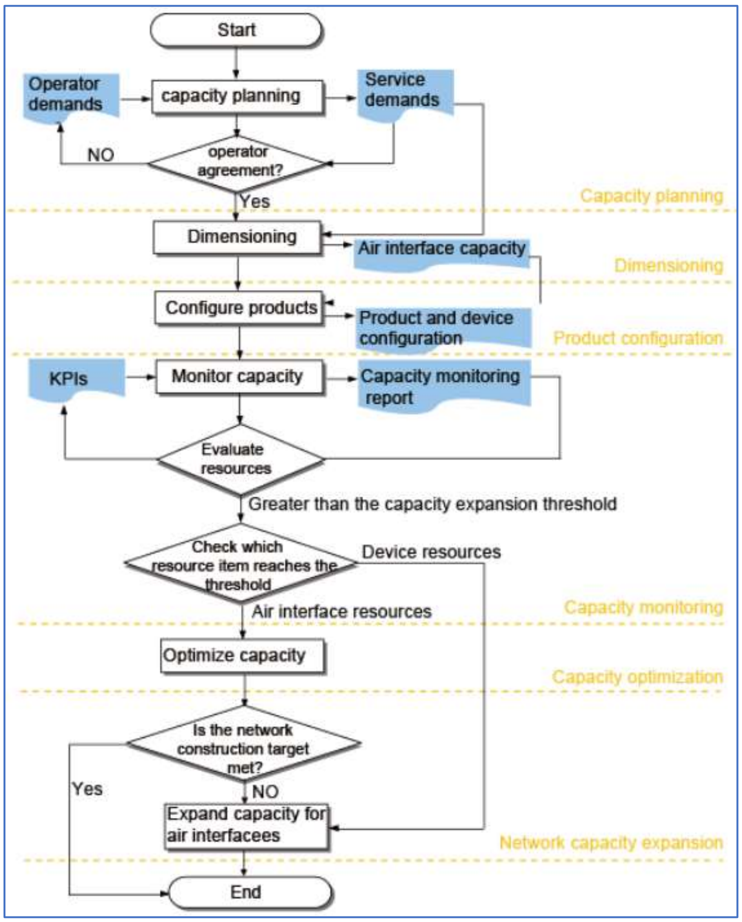
Being a greenfield NW for CGx , Radisys will offer the generic capacity services for evaluating and planning network capacity. We anticipate that by doing this exercise , a live network congestion can be eliminated by analyzing the network capacity bottleneck. Future capacity demands can be planned based on the network capacity prediction.

- Requirements from CGx is 100/10 mbps DL/UL on 20/40 MHz with 256QAM DL are operators' network construction requirements, including traffic demands to cover >50 homes per site and user experience assurance like >=100 mbps and no throttling.
- 100 Mbps and service KPI planning and NW's capability needs to be evaluated based on 100Mbps and service KPIs to generate advice on capacity planning. Parameters like NR connected CPEs, active CPEs, available PRBs , cell total PRBs, MCS , CQI are the main one which will aid our planning to get the desired throughput. The bearer rate varies according to the service type. Radisys and CGx agreed for eMBB services in phase 1 with no mobility. This can be classified into web, video, social networking, instant message, email, file transfer, gaming services. 100Mbps for different types of services to ensure good user experience is shown as below:



- We need to simulate the CPE capability in good RF and air interface loads on the live network to decide the current capacity status and bottleneck.

- find when the network is overloaded based on a certain criterion. The criterion can be resource type-specific capacity expansion thresholds or be defined based on the capacity load or congestion of the live network.
- If the usage of a type of resource exceeds the respective capacity threshold, perform capacity expansion for this type of resource and decrease the target load to 10% of the capacity threshold.
    - Predict the future capacity demands based on the future traffic model and resource load growth factor.
- If the usage of a type of resource does not exceed the capacity threshold, predict the future capacity demands based on the current traffic model and service load. – *Futuristic*
- There are various factors causing an increase in resource load:
    - Traffic Factor indicates the increase multiples of traffic on the 5G network during peak hours.
    - Peak hour PRB utilization reaches 100%
    - Average/peak throughput indicates the downlink single-subscriber-perceived throughput rate expected by operators. The default throughput rate is 100 Mbit/s, which can meet most 5G service demands. This will indicate if further capacity is needed then in what form – more MIMO, more sites or more spectrum or mix of few.



Radisys will perform the evaluation of grid-level rate capability, calculate the theoretical rate of each grid based on the CQI, estimated RSRP/SINR , # of CPEs , and available power in this grid, and then geographically display the rates in the grids.
Radisys will also advice on carrier capacity expansion and site planning through simulation and positioning based on the difference between the current grid-level rate capability and the target rate.

13. Congestion and Load management

Congestion control we anticipate in FWA will be primarily driven due to insufficient of radio resources. As the cell load varies and the quality of admitted services gets affected, even if the # of users in the cell does not change. Radisys expect to have some way to handle the congestion control algorithm.
FWA of CGx is a best effort and Radisys RAN will not discriminate the CPEs in terms of QoS but in terms of access class. When the cell is congested, we anticipate that congestion control releases the low access class CPEs first to make some resources available. The release reduces system load and helps ensure the quality of other admitted services. Our algorithm immediately informs the admission control algorithm to reject all access requests and, in addition, takes actions to reduce cell load.
How must RAN identify that cell is congested and loaded? Just PRN utilization is not a good indicator instead we must adopt to define QoS based thresholds.
A cell is regarded as congested in the DL if the DL QoS satisfaction/agreed rate QCIs is lower than the relevant congestion threshold.
A cell is regarded as congested in the UL if the UL QoS satisfaction/agreed rate QCIs is lower than the relevant congestion threshold and the UL PRB usage is high, or the wait time for uplink scheduling is too long.
The congestion control algorithm increases the service drop rate because the congestion control-triggered releases of CPEs are regarded as service drops.

14. When to Use Admission and Congestion Control

When a FWA DU becomes congested due to increasing number of CPEs and higher QoS requirements, O-CU need to perform radio resource management so that QoS requirements of ongoing services can be fulfilled and differentiated services can be provided.
But when radio resource congestion occurs (QoS requirements cannot be fulfilled or radio bearers cannot be set up), activate admission control to relieve congestion and provide "***access-priority-based***" services.
When congestion increases so that QoS requirements still cannot be fulfilled, activate congestion control to releases services of low access class first.

15. Wireless Capacity model for FWA

There is a fixed and finite amount of network capacity CGx will be able to offer because of the allocated BW from SAS. Each CPE will be sharing the same spectrum, so as more users demand more capacity, data on the network will travel slower for each user. But that could happen only when all are trying to use the wireless network in that area at the same time. In simple terms, the wireless signal from an antenna or "beam" is used by all users served by this antenna, such that the wireless capacity is necessarily divided amongst all these users and leaving less capacity for other CPE.
So, to be an attractive offering, we recommend CGx to consider the "***Oversubscription to wireless network design***" (or the design of any network with elements of shared capacity).
To get better understanding, let us assume that there are 20 CPEs sharing an cell of 20 MHz, and each user has subscribed to 100 Mbps service, that would indicate the potential for 2 Gbps of capacity use (20 * 100 Mbps), it is unnecessary to design the system for that level of capacity because not all users will typically require their full speed exactly at the same time. To account for this, network engineers use the concept of "oversubscription " which defines how many times CGx "resell" the same network capacity where it is shared among multiple CPEs/Homes of that network.
We are recommending the oversubscription ratio of 5:1 to the example above, only 400 Mbps of capacity rather than 2 Gbps would be needed in that cell of 20 MHz to serve the 20 customers (each subscribed to a 100 Mbps broadband package).

To increase the wireless speed and capacity that can be offered to their customers, CGx will try to reduce the number of customers served by a cell by increasing the # of sites serving a given area - "network densification." But because of dense trees and n48 absorption , Rsys will recommend that an effective wireless network design in a rural area will be considered with trade-offs between power, potential for interference, antenna height, and topography.
Following is the proposal we shared with CGx:

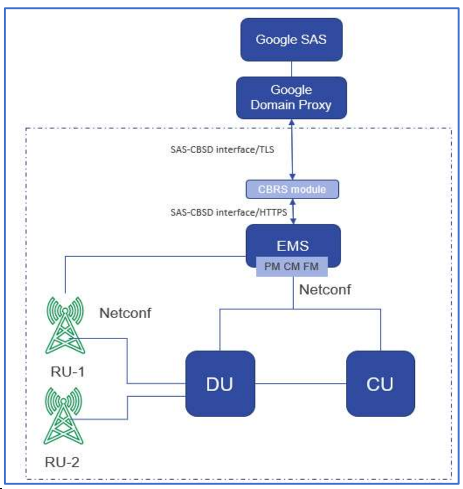
Oversubscription modeling – Recommended for outdoor CPE at each households

Oversubscribe Ratio	Cell center (~400 meter) – 100+ mbps ptp link offerings to households - 3 options			Mid range (~650 meter) – 80+ mbps ptp link offerings to households – 3 options			Cell edge – 50+mbps ptp link offerings to households -3 options		
	10MHz 3x100 mbps	20 MHz 3x220mbps	40 MHz 3x480 mbps	10MHz 3x80 mbps	20 MHz 3x170mbps	40 MHz 3x360 mbps	10 MHz 3x45 mbps	20 MHz 3x90 mbps	40 MHz 3x230 mbps
15:1 per site (5:1 per cell)	3x5 homes 15 homes	3x5x2.2 homes 33 homes	3x5x4.8 homes 72 homes	3x5x0.8 homes 12 homes	3x5x1.7 homes 25 homes	3x5x3.6 homes 54 homes	3x5x0.45 homes 7 homes	3x5x0.9 homes 13 homes	3x5x2.3 homes 32 homes
30:1 per site (10:1) per cell	3x10 homes 30 homes	3x10x2.2 homes 66 homes	3x10x4.8 homes 144 homes	3x10x0.8 homes 24 homes	3x10x1.7 homes 50 homes	3x10x3.6 homes 108 homes	3x10x0.45 homes 14 homes	3x10x0.9 homes 26 homes	3x10x2.3 homes 64 homes

- Oversubscription relies that not all households are active even in the busy hour.
- Let us use this multiplexing gain to provision their network capacity below the absolute maximum demand

EMS -OAM Enhancements

Following is the proposed architecture for CBRS-OAM module which can sit with existing EMS and can interact with DP.



16. Counters in EMS-OAM specific for CBRS

Counter Name	Description of Counter	Data Type	Triggering Condition
CBSD Registration Requests	EMS initiated # of CBSD Registration Requests towards SAS	Integer	When CBSD (RU-DU) boots up ; Registration Request is sent to the SAS through EMS
CBSD Registration Responses	# of EMS-CBSD Registration Responses from SAS	Integer	When CBSD Registration response received from SAS
CBSD Registration Successes	# of EMS-CBSD Registration Success Responses from SAS	Integer	When CBSD Registration Success Response received from SAS , “+” outcome
CBSD Registration failures	# of EMS-CBSD Registration denied/failures Responses from SAS	Integer	When CBSD Registration Success Response received from SAS with “-“ result

CBSD Registration failures	# of EMS-CBSD Registration denied/failures Responses from SAS	Integer	When CBSD Registration failure Response received from SAS with , due to missing or incorrect parameters within CBSDInfo parameter
CBSD Grant Requests	EMS initiated # of CBSD Grant Requests to SAS	Integer	When EMS-CBSD Grant Request sent to SAS
CBSD Grant Responses	# of CBSD Grant Responses from SAS	Integer	When CBSD Grant Response received from SAS
CBSD Grant Successes	# of EMS-CBSD Grant Success Responses from SAS	Integer	When CBSD Grant Success Response received @ EMS from SAS
CBSD Grant Fail	# of EMS-CBSD Grant fails Responses from SAS	Integer	When CBSD Grant fails Response received @ EMS from SAS - due to existing interference)CC#400)
CBSD Grant Fail	# of EMS-CBSD Grant fails Responses from SAS	Integer	When CBSD Grant fails Response received @ EMS from SAS - due to grant conflict ,CC#401
CBSD Grant Fail	# of EMS-CBSD Grant fails Responses from SAS	Integer	When CBSD Grant fails Response received @ EMS from SAS - due to certification error
CBSD Grant Fail	# of EMS-CBSD Grant fails Responses from SAS	Integer	When CBSD Grant fails Response received @ EMS from SAS - due to missing parameters
CBSD Relinquishment Requests	# of EMS-CBSD Grant Relinquishment requests towards SAS	Integer	When CBSD Grant Relinquishment Request is sent to the SAS from EMS
CBSD Relinquishment Responses	# of EMS- CBSD Grant Relinquishment responses from SAS	Integer	When CBSD Grant Relinquishment Response received @ EMS from SAS
CBSD Relinquishment Successes	# of EMS - CBSD Grant Relinquishment Success Responses from SAS	Integer	When CBSD Grant Relinquishment Success Response received @ EMS from SAS
CBSD Spectrum Inquiry Request	# of EMS Spectrum Inquiry Requests towards SAS	Integer	When CBSD Spectrum Inquiry Request is sent to the SAS
CBSD Spectrum Inquiry Response	# of EMS Spectrum Inquiry Responses from SAS	Integer	When CBSD Spectrum Inquiry Response received from SAS
CBSD Spectrum Inquiry Successes	# of CBSD Spectrum Inquiry Success Response from SAS	Integer	When CBSD Spectrum Inquiry Success Response received from SAS
CBSD Spectrum Inquiry denied	# of EMS- CBSD Spectrum Inquiry Fail Response from SAS	Integer	When CBSD Spectrum Inquiry fails Response received from SAS - due to existing interference)CC#400)
CBSD Deregistration Requests	# of CBSD Deregistration requests towards SAS	Integer	When CBSD Deregistration Request is sent to the SAS
CBSD Deregistration Responses	# of CBSD Deregistration responses from SAS	Integer	When CBSD Deregistration Response received from SAS
CBSD Deregistration Successes	# of CBSD Deregistration success response from SAS	Integer	When CBSD Deregistration Success Response received from SAS
CBSD suspended grant	# of suspended grant initiated from SAS and sent to EMS or EMS initiated	Integer	When SAS decided and/or EMS initiated to suspend the grant due to transmit expiry timer
CBSD terminated grant	# of terminated grant initiated from SAS and sent to EMS	Integer	When SAS decided and/or EMS initiated to terminate the grant due to RF violation/Interference experienced by SAS
CBSD grant failure	# of failed grant initiated from SAS and sent to EMS	Integer	When SAS decided to reject the grant due miscellaneous reasons, not listed above

CBSD registration failure	# of failed registration initiated from SAS and sent to EMS	Integer	When SAS decided to reject the initial registration due miscellaneous reasons, not listed above

17. List of CBRS specific alarms – EMS-OAM

Event Name	Severity	Type	Raising condition	Clearing condition
CBSD Registration Failures	Critical	Reporting	Reported by EMS-DP when there is failure response from SAS or there is no response for the registration request sent by EMS-DP , EMS tracks this	
CBSD Heartbeat Failures	Critical	Reporting	Reported by google Domain Proxy when there is failure response from SAS or there is no response for the heartbeat request sent by Domain Proxy, EMS will be notified	
CBSD Relinquishment Failure	Critical	Reporting	Reported by EMS- DP when there is failure response from SAS or there is no response for the grant relinquishment request sent from EMS-DP.	
CBSD Spectrum Inquiry Failure	Critical	Reporting	Reported by EMS-DP when there is faiure response from SAS or there is no response for the spectrum Inquiry request sent from EMS-DP.	
CBSD Deregistration Failure	Critical	Reporting	Reported by EMS-DP when there is failure response from SAS or there is no response for CBSD de-registration request.	
SAS Unreachable	Critical	Reporting	SAS is not reachable. EMS-DP initiated failure alarms	
Domain Proxy Unavailable	Critical	Reporting	EMS initiated this when EMS fails to connect to DP/HB/CBSD Interface protocols..	
SAS URLs unresolved	Critical	Reporting	EMS – DP not able to resolve default SAS URL due to miss-configurations	
KPI Grant Failures	Major	Reporting	% of Grant Failures greater than 2%	Cleared once the % of Grant Failures < 2%
KPI Registration Failures	Major	Reporting	% of CBSD registration failures greater than 2%	% of CBSD registration failures < 2%

18. System KPIs in EMS

Detail list of such KPI/formulas as per the *3GPP TS 32.425: Performance Management (PM); Performance measurements - Evolved Universal Terrestrial Radio Access Network (E-UTRAN).*

KPI – PM and overview	Description
DCR (Dropped Call Rate)	To calculate Dropped Call rate, use the following formula: (100*A)/(B+C) A = Number of dropped calls , B = Number of additional E-RABs successful to setup C = Number of initial E-RABs successful to setup ,
RRC Connection Establishment Success rate	To calculate RRC Connection Establishment Success rate, use the following formula: (∑A/∑B)*100 , A = Number of RRC connection establishment successes B= Number of RRC connection establishment attempts
RRC Connection Re-establishment Success rate	To calculate RRC Connection Re-establishment Success rate, use the following formula: (∑A/∑B)*100 A = Number of RRC connection re-establishment successes B= Number of RRC connection re-establishment attempts
Initial D-RAB Setup Success rate	To calculate initial D-RAB Setup Success rate, use the following formula: (∑A/∑B)*100 A = Number of initial D-RABs successful to setup B = Number of initial D-RABs attempted to setup
Initial data Bearer Setup Success Rate	To calculate Initial Bearer Setup Success rate, use the following formula: (A*100)/B A = Number of initial D-RABs successful to setup B = Number of initial D-RABs attempted to setup
Handover Success rate	To calculate Handover Success rate, use the following formula: (∑A/∑B)*100 A= Number HO successes B = Number HO attempts
SAS Availability	To calculate SAS Availability, use the following formula: [(A-B)/A]*100 A = Measurement Period B = SAS unavailable time
CBSD Cell Availability	To calculate cell availability, use the following formula: [(A-B)/A]*100 A = measurement_period B = sum of cell unavailable time
Average number of Active UEs	To calculate average number of active UEs, use sum of all UEs in O-CU.
Total DL Traffic Volume (GBytes)	To calculate total DL traffic volume per site , use : ∑ of all dlTrafficVolume reported from PDCP-U counter in a given interval of reporting time.
Total UL Traffic Volume (GBytes)	To calculate total UL traffic volume per CBSD, use:∑ of all ulTrafficVolume reported for PDCP-U counter in a given interval of reporting time.
Average DL Throughput (Mbps)	To calculate per cell/site,
Average UL Throughput (Mbps)	To calculate per cell/site
% of Grant Failures	No of Grant Failures / No of Grant Requests * 100
% of CBSD registration Failures	No of CBSD Registration Failures / No of CBSD Registration Requests * 100
% of CBSD timeouts	No of CBSD request messages / No of CBSD response messages * 100

19. 3GPP Validation KPIs for field and commercial deployments

	Category	Benchmarking/Thresholds	KPIs to monitor and optimize
1	CPE Accessibility 5G DATA (Success rate of setup of total sessions (RRC, SRB/DRBs , N2 and 5G-RAB e2e)	>95%	MO/MT Access : # RRC paging messages , RACH Setup Completion Success Rate , RRC Connection Setup Success Rate , E-RAB Setup Success Rate - non - GBR/default bearer/AMBR , N2 Initial Context Setup Success Rate,
2	CPE Retainability 5G DATA (Success rate of not dropping E-RAB ratio (RRC, SRB/DRBs , N2 and 5G-RAB e2e)	>95%	MO/MT Access : E-RAB Active Time non-GBR , E-RAB drop ratio due to other (OTH) cause initiated be gNB , E-RAB Drop Ratio per Cause OTH AMF , E-RAB Normal Release , E-RAB Release ratio due to Radio resources not available , E-RAB Retainability Rate with RNL Failure with CPE Lost
3	RRC validation for multiple scenario cause value for RRC Connection Establishments: 1) MO-SIGNALLING 2) MO-DATA 3) MO-Others 4) MT-ACCESS 5) HIGH_PRIORITY_ACCESS 6) RRC-Re-establishment (Same Cell)	>95%	MO/MT Access : RRC Connection Establishment Success Ratio per cause – MO sig, MT Access, MO data, Re-establishment Success Ratio , RRC Connection Setup Failure Ratio , "RRC timer expiry" failure , RRC Releases -Unknown
4	N2 validation for multiple scenario cause values for NGAP Connection Establishments: 1) MO-SIGNALLING 2) MO-DATA 3) MO-Others 4) MT-ACCESS 5) HIGH_PRIORITY_ACCESS 6) RRC-Restablishment (Same Cell)	>95%	CPE associated Signalling : N2 Initial Context Setup Success Ratio per cause – MO sig, MT Access, MO data, Re-establishment Success Ratio , Paging Success Non-CPE associated Signalling : N2 setup success (NGAP) , N2 Setup Failure Ratio per Cause No_RESP/Resource/RNL , setup failure due to timer expiration , reset initiated by gNB - link resumes , reset initiated by AMF -link resumes
5	4X4 MIMO Utilization (spectral Efficiency at MAC layer) : assume 256QAM/256 QAM with 40 MHz and 4L/2L	DL >15 b/s/Hz , UL >3 b/s/Hz	Check transmission-mode parameter , SINR and CQI reporting to gNB along with RI index in logs 4X4 MIMO with RI=1 : CPE at cell edge or interference/ or fast CPE 4X4 MIMO with RI=2 : CPE and reasonable RSRP/slow fading 4X4 MIMO with RI=3 : Perfect RF/No mobility
6	Integrity (Quality & Power) (CQI ,SINR, Re-Tx data) overall Quality check of the coverage experienced by the CPE	0-15 (WB/Sub-Band and Average CQI)	Average CQI for a session (DL only , UL only , DL & UL), Average SINR for PUSCH, Average RSSI maintained for PUSCH/PUCCH for active session , RLC discard data .MAC re-transmission data , DL RSRP/RSRQ average
7	Paging Discard Rate	<10%	Look for Paging Parameters in SIB2 /Paging occasions and finally the CPE-ID in paging message and CPE still discards. Validate at ORAN if paging went through at OTA.
8	Throughout & Cell Resource 1) Single CPE Peak DL & UL Data Rate for 20 and 40 MHz 2) Multi-CPE (32, 64, 128,) DL & UL Data Rate for 20 and 40 MHz	SF:46 ,20 MHz ,DL >230 Mbps SF:46 , 100 MHz , DL >1.3 Gbps PRB Utilization (PDSCH) : 80%-100%	Maximum of Average Active Connected CPEs, Signalling throughput over Xn/N2, Data throughput over Xn/N2, Average PRB usage per TTI UL/DL, Average RLC Layer Cell Throughput UL/DL ,Average PDCP Layer Cell Throughput UL/DL , Peak/Average throughput : consistency and RF tuning (4T4R+256QAM) with different use cases : streaming/FTP/UDP : All OTA with 3 cells config under one DU.
9	Maximum RRC connected CPE (SW licenses /server capability) that O-CU has allocated resources to all CPEs, admission successes, admission failures, incoming-handover successes, and incoming handover failures. It will indicate the need of capacity expansion.	>100 Active CPEs	Average of users connected to O-CU with active DRB/SRB: "RRCconnmax"
10	CPU utilisation (O-DU/O-CU/CCDU) Min/Max/Average values	20% to 80% utilization/power dissipation	maximum possible use of the O-DU/O-CU/CCDU CPU utilied for 4X4/4L+256QAM+40 MHz in the period.
11	Packet loss Rate PDCP SDU/PDU loss rate RLC SDU/PDU loss rate	<10% BLER	Measure PLR for UL/DL for default bearer for 5QI, static/low motion CPE with different services: FTP/UDP/Streaming and kepe BLER as low as possible.
12	Transport /resiliency (Local HW resiliency) success rate of services 1) SCTP associations 2) EGTP/GTP associations	100% resiliency	Active -standby or Hot-Cold configuration among : Primary down then secondary up : 1) O-DU to O-CO (F1-C/F1-U link reset and comes alive) 2) Validate for E1 interface if available else validate Xn interfaces (Xn-C/Xn-U) 2) O-CU to AMF (N2 link resets and comes alive) 3) O-CU to UPF (N3 link resets and comes alive)

20. Network Architecture for Circle Gx with NR-CBRS

20.1. PNF gNBs +EMS as a CBSDs

When using a VNF/CNF option for DA, the relationship between the CBSD and gNB gets a little more complicated. The CBSD is tied to the transmission point of the gNB – the antenna and the RRH, rather than the DU-CU. But for this project , Radisys solution will have distributed functions/procedures on different network elements. E.g.3rd party RRH (Airspan) will support n48 with SCF option 6 under transmission power requirement of FCC part 96. But the turn on/off of this RU will be controlled by DU-EMS. DU on other hand will get the ARFCN from EMS prior to bring the cell up . DU will wait for EMS to receive the cell config file having EARFCN/EIRP/BW/Tx expiry timer). A CNF/VNF form of DU will configured with multi-instances (roughly 12 pCore for each instance) for multi-MNO isolations. Each DU instances will have F1-C/F1-U towards another multi-instances of O-CU. O-CU which will be centralized and in split mode (CU-CP/CU-UP) will support F1-C/F1-U towards respective O-DU . One DU will terminate to one CU only. Also , respective instances of CU-C/P will terminate to MNO's dedicated 5GC instances (N2/N3 -AMF-UPF).

Physical layer resources will be shared among all participants MNOs and for this , a common DU or VNF-DU ideal, this is still TBC and for FFS.

For such deployment , latency must be <800 usec RTT (RRH<->CU) , 150 usec for transmission only. TDD/FDD synchronization is very crucial hence <16 ppb for frequency synchronization and <3 usec for TDD synchronization. With O-RU supporting 4X4 MIMO, Radisys recommends having ~ 10GB link FH connections.

Midhaul with 300-500 mbps will be sufficient over the ethernet.

The EMS-OAM will manage the CBRS portion on behalf of CBSD. Proposed EMS will have new CBRS module which will interact with Google DP/SAS as listed below.

Hence for final FCC certification , proposed CBSD will have ***RU-DU-CU-EMS*** as full ecosystem.

To address NR-CBRS NW security , Radisys assume to leverage the cryptographic security has been built into 3GPP networks since their inception, and the use of USIM-based security mechanisms to authenticate UEs is well established.

21. Network configuration for CGx with NR-CBRS

NR-CBRS in CGx is a traditional CBRS design having only spectrum is a variable factor. This need few enhancements though in DU mainly as well as in EMS and some limited support in 5GC to enable e2e services.

21.1. PLMN handling and NW selection

In order to determine to which PLMN to attempt registration, the CPE performs network selection. The network selection procedure will have two main parts, PLMN selection and access network selection. The requirements for the PLMN selection are specified in TS 22.011 and the procedures are in TS 23.122 .

The access network selection part for the 3GPP access networks is specified in TS 38.300 for the NR. It will be exactly same and please do not forget to replace UE with CPE in both specs.

21.2. Serving Cell Common Configuration

SIB1 Serving Cell Common information is used to configure cell specific parameters of a UE's serving cell in respective PLMN. Key info here is the unlicensed spectrum n48 DL frequency information, Initial DL (BWP), paging channel configuration , RACH-ConfigCommon, PUSCH-ConfigCommon, PUCCH-ConfigCommon etc.

```
servingCellConfigCommon
    DownlinkConfigCommonSIB
        frequencyInfoDL
            frequencyBandList           MultiFrequencyBandListNR-SIB
                freqBandIndicatorNR                                 INTEGER       (1…1024)
                nr-NS-PmaxLbt           SEQUENCE [1 to 8 instances]
                    additionalPmax                                  INTEGER       (-30…33)
                    additionalSpectrumEmission                      INTEGER       (1…288)
            offsetToPointA                                          INTEGER       (0…2199)
            scs-SpecificCarrierList                                 SEQUENCE      (SIZE (1…maxSCSs))
        initialDownlinkBWP
            BWP-DownlinkCommon
                locationAndBandwidth                                INTEGER       (0…37949)
                subcarrierSpacing                                                 (15 khz,30 khz,60 khz,120khz)
                cyclicPrefix                                        ENUMERATED    {extended}
        bcch-Config
            modificationPeriodCoeff                                 ENUMERATED    {n2, n4, n8, n16}
        PCCH-Config
            defaultPagingCycle          PagingCycle,
            nAndPagingFrameOffset
                oneT                                                                  NULL,
                halfT                                               INTEGER           (0…1)
                quarterT                                            INTEGER           (0…3)
                oneEighthT                                          INTEGER           (0…7)
                oneSixteenthT                                       INTEGER           (0…15)
            ns                                                      ENUMERATED        {four, two, one}
```

The IE Cell Access Related Info indicates cell access related information for this cell.

– *CellAccessRelatedInfo*

The IE *CellAccessRelatedInfo* indicates cell access related information for this cell.

***CellAccessRelatedInfo* information element**

```
-- ASN1START
-- TAG-CELLACCESSRELATEDINFO-START

CellAccessRelatedInfo   ::=         SEQUENCE {
    plmn-IdentityInfoList               PLMN-IdentityInfoList,
    cellReservedForOtherUse             ENUMERATED {true}           OPTIONAL,   -- Need R
    ...,
    [[
    cellReservedForFutureUse-r16        ENUMERATED {true}           OPTIONAL,   -- Need R
    npn-IdentityInfoList-r16            NPN-IdentityInfoList-r16    OPTIONAL    -- Need R
    ]],
    [[
    snpn-AccessInfoList-r17             SEQUENCE (SIZE (1..maxNPN-r16)) OF SNPN-AccessInfo-r17    OPTIONAL    -- Need R
    ]]
}

SNPN-AccessInfo-r17 ::=         SEQUENCE {
    extCH-Supported-r17                 ENUMERATED {true}           OPTIONAL,   -- Need R
    extCH-WithoutConfigAllowed-r17      ENUMERATED {true}           OPTIONAL,   -- Need R
    onboardingEnabled-r17               ENUMERATED {true}           OPTIONAL,   -- Need R
    imsEmergencySupportForSNPN-r17      ENUMERATED {true}           OPTIONAL    -- Need R
```

SIB1 contains information relevant when evaluating if a UE is allowed to access a cell and Cell Access related Info is part of SIB1.

```
SIB1 ::=        SEQUENCE {
    cellSelectionInfo                   SEQUENCE {
        q-RxLevMin                          Q-RxLevMin,
        q-RxLevMinOffset                    INTEGER (1..8)                      OPTIONAL,   -- Need S
        q-RxLevMinSUL                       Q-RxLevMin                          OPTIONAL,   -- Need R
        q-QualMin                           Q-QualMin                           OPTIONAL,   -- Need S
        q-QualMinOffset                     INTEGER (1..8)                      OPTIONAL    -- Need S
    }                                                                           OPTIONAL,   -- Cond Standalone
    cellAccessRelatedInfo               CellAccessRelatedInfo,
    connEstFailureControl               ConnEstFailureControl                   OPTIONAL,   -- Need R
    si-SchedulingInfo                   SI-SchedulingInfo                       OPTIONAL,   -- Need R
    servingCellConfigCommon             ServingCellConfigCommonSIB              OPTIONAL,   -- Need R
    ims-EmergencySupport                ENUMERATED {true}                       OPTIONAL,   -- Need R
    eCallOverIMS-Support                ENUMERATED {true}                       OPTIONAL,   -- Need R
    ue-TimersAndConstants               UE-TimersAndConstants                   OPTIONAL,   -- Need R
    uac-BarringInfo                     SEQUENCE {
        uac-BarringForCommon                UAC-BarringPerCatList                   OPTIONAL,   -- Need S
        uac-BarringPerPLMN-List             UAC-BarringPerPLMN-List                 OPTIONAL,   -- Need S
        uac-BarringInfoSetList              UAC-BarringInfoSetList,
        uac-AccessCategory1-SelectionAssistanceInfo CHOICE {
            plmnCommon                          UAC-AccessCategory1-SelectionAssistanceInfo,
            individualPLMNList                  SEQUENCE (SIZE (2..maxPLMN)) OF UAC-AccessCategory1-SelectionAssistanceInfo
        }                                                                           OPTIONAL    -- Need S
```

21.3. Identification and authentication

In the case of CPE connected via FWA, the specification defined in TS 23.501 clause 5.2.3 applies with the following difference: - UE is replaced by CPE. The network may authenticate the UE during any procedure establishing a NAS signalling connection with the UE. The security architecture is specified in TS 33.501.

21.4. Authorisation

In the case of CPE connected via FWA, the specification defined in TS 23.501 clause 5.2.4 applies with the following differences: - UE is replaced by CPE.

The authorization for connectivity of the CPE to the 5GC and the authorization for the services that the user is allowed to access based on subscription (e.g. Operator Determined Barrings, Access Type and RAT Type currently in use) is evaluated once the user is successfully identified and authenticated. This authorization is executed during CPE Registration with 5GC procedure.

21.5. Access control and barring

When the CPE needs to transmit an initial NAS message, the CPE shall request to establish an RRC Connection first tpwards O-CU , and the NAS shall provide the RRC establishment related information to the lower layer. The CU shall handles the RRC Connection with access priority class and admission criteria during and after RRC Connection Establishment procedure, when CPE indicates priority in Establishment related information.

Under high network load conditions, the CU may protect itself against overload by using the Unified Access Control functionality for 3GPP access specified in TS 22.261 , TS 24.501 and TS 38.300 to limit access attempts from CPEs. More details in Appendix.

Note : O-CU may initiate such Unified Access Control on itself.

For access control , Rsys may configure PLMN-specific Operator-defined access category definitions to the CPE using NAS signalling, and the CPEE handles the Operator-defined access category definitions stored for the Registered PLMN, as specified in TS 24.501.

21.6. Policy Control

The policy and charging control framework for the 5G System is defined in TS 23.503 and will be outsourced for Rsys's 5GC. No RAN dependency. *Policy control is just optional* till we dont enable services like voice or dedicated bearer.

To support the CPE lock for binding services of a subscriber/ UICC to a specific CPE, the UDM/UDR, & AMF capabilities are required: for CPE policy controls locally if PCF is not used. Like : PEI provisioning (IMEI in this case) on the UDR associated with a UICC .

21.7. LI enablement

For definition and functionality of Lawful Interception, please see TS 33.126. Rsys 5GC will open the interface for LI: allows appropriate authorities to perform interception of communication traffic for specific CPEs and this includes activation, deactivation, interrogation, and invocation procedures. To enable this , CGx will need to have new Nes like addition functions like Administration Function (ADMF) and Mediation and Delivery Function (MDF).
Administration Function (ADMF) is responsible for the overall management/control plane of the LI system. ADMF uses the LI_X1 interface toward the 5G Core Network Functions (NFs) for managing the LI functionality. On other hand , Mediation and Delivery Function (MDF) delivers the interception reports to the Law Enforcement Monitoring Facility (LEMF).
Still not planned for phase 1 so this section is for Info only.

21.8. Mobility & Handover cases

Current focus is for FWA as of now and CPE is a UE here which is static always. So not planned but CGx wants to expand this for smart phones as well in later release with phased approach.

21.9. Xn Setup

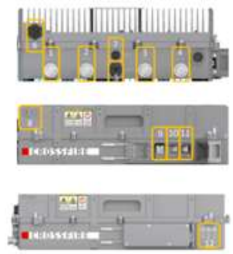
Same as above section 20.7.

21.10. F1Setup

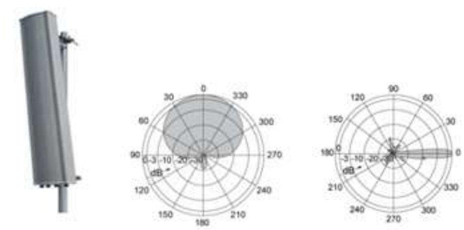
A combo CU-DU unit and F1 is not exposed No strict requirements proposed for F1.

22. RU/Antenna – Sunwave's M2ru – n48 SW/FW

Technology	5GNR in Sub-6 GHz
TRx Configuration	4T4R or dual band in 2T2R
Composite Output Power	46dBm
EVM	<3.5% @ 256QAM
Power Supply	48VDC±20% | 100-240VAC
Power Consumption	650W
Operating Temperature	-40°C to +50°C
Dimension	500 x 142 x 380 mm
Weight	24Kg
Synchronization	1588V2
Ingress protection	IP65



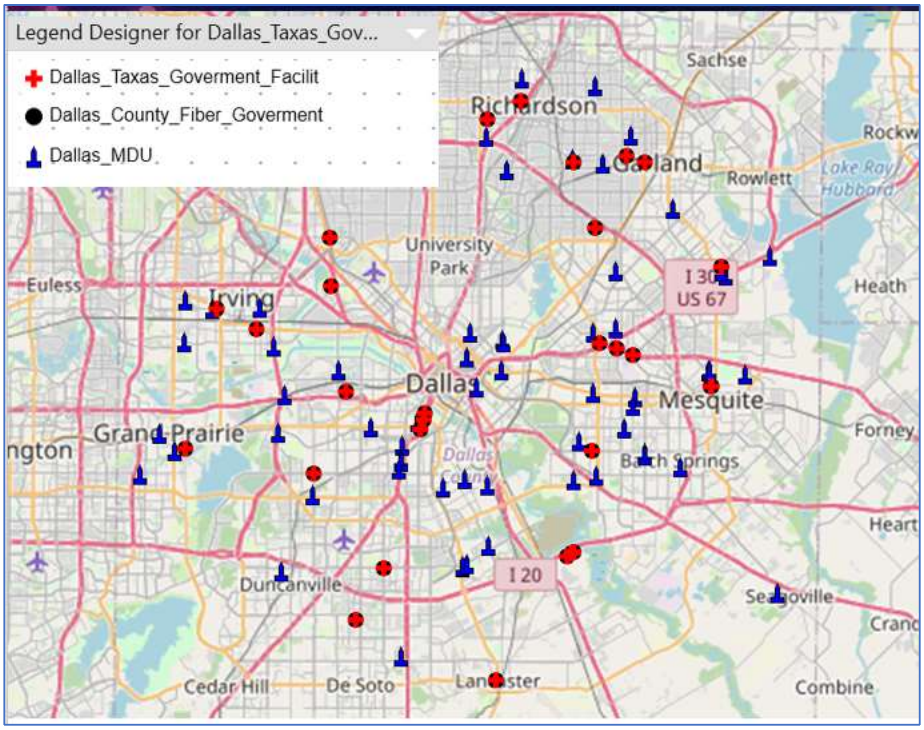
1	Duplex DL/UL RF Port 1	2	Duplex DL/UL RF Port 2
3	Duplex DL/UL RF Port 3	4	Duplex DL/UL RF Port 4
5	External Alarm Port	6	Power Socket Interface
7	AISG Port	8	GND
9	Maintenance Interface	10	OP Port for DU Connection
11	OP Port for Cascade	12	LED Indicator of OP & System



Frequency range	3550-3700 MHz
Polarization	Vertical
Gain (dBi)	16.5
electrical down tilt (°)	0-10
Horiz. beam width (°)	70±5
vertical beam width (°)	≥8
Maximum power (W)	200
Height/width/depth (mm)	580*280*80
Limit wind velocity (km/h)	110
Operating temp. (℃)	-40~+60

23. Transport

In CGx's model of FWA , Radisys will leverage the transport infrastructure provided and recommended by CGx and its partners. There will be a shared transmission network, provide error isolation, load sharing and create an architecture ready for convergence of the shared network. In phased approach , Radisys assumes that CGx's transport network for the RAN and 5GC can also utilize network automation techniques as in future when DU/CU migrated to localized or centralized GCP/GDC The overall traffic from/to RU will reach to the centralized DU (DU in localized GCP) through Mobile fronthaul Aggregation Router (MFAR) of the participants MNO. Similarly , mobile Backhaul router will be configured with SRIOV/OSPF routing mechanism. Radisys also recommends and assume that each service will be carried through a separate VPN. To prevent problems in case of ever-increasing interconnections between in future, a *separate prefix list* should be created for each service. Each user traffic belonging to different MNOs are separated by VLANs between the MFAR/MBAR.
CGx will leverage existing DF when available but prefer to consider Wireless BH. Hence Rsys shall propose a "*Hybrid Fiber Wireless*" solution. This is disruptive model to build GTTH on proven technology. This model needs wireless BH from provider like EB Link/Tarana and others plus another un-licensed spectrum which is rich in bandwidth :i.e. (5GHz). This will reduce the deployment cost, quick time to market and compliment the DF.
PtP systems rely on directional antenna on each end to focus the signal and typically consist of more expensive equipment. Because of the focused beam, they can often achieve longer distances than PtMP systems.
Below are the locations of available data center facility where DF does exist today which we can leverage.



Legend Designer for Dallas_Taxas_Gov...
Dallas_Taxas_Goverment_Facilit
Dallas_County_Fiber_Goverment
Dallas_MDU
Sachse
Richardson
Rockw
Garland
Rowlett
Lake Ray Hubbard
University Park
Euless
Irving
I 30
US 67
Heath
Dallas
Mesquite
Forney
Grand Prairie
ngton
Balch Springs
Heart
I 20
Duncanville
Seagoville
Cranc
Cedar Hill
De Soto
Lancaster
Combine

24. Appendix

24.1. Admission control and Unified access control

Description: Depending on operator policies, deployment scenarios, subscriber profiles, and available services, different criterion will be used in determining which access attempt should be allowed or blocked when congestion occurs in the 5G System. These different criteria for access control are associated with Access Identities and Access Categories. The 5G system now has a single unified access control where operators control access attempts based on these two aspects. In unified access control, each access attempt is categorized into one or more of the Access Identities and one of the Access Categories. The unified access control supports flexibility to allow operators to define *operator-defined Access Categories using their own criterion* (e.g., application, and application server and more). The unified access control framework shall be applicable to CPEs in RRC Idle, RRC Inactive, and RRC Connected at the time of initiating a new access attempt (e.g. "new session request" in RRC Connected refers to events, new MMTEL voice or video session, sending of SMS (SMS over IP, or SMS over NAS), new PDU session establishment, existing PDU session modification, and service request to re-establish the user plane for an existing PDU session. For further details, please refer to *TS 22.261 R15.3.0 onwards*.

Table 6.22.2.3-1: Access Categories

Access Category number	Conditions related to UE	Type of access attempt
0	All	MO signalling resulting from paging
1 (NOTE 1)	UE is configured for delay tolerant service and subject to access control for Access Category 1, which is judged based on relation of UE's HPLMN and the selected PLMN.	All except for Emergency
2	All	Emergency
3	All except for the conditions in Access Category 1.	MO signalling on NAS level resulting from other than paging
4	All except for the conditions in Access Category 1.	MMTEL voice (NOTE 3)
5	All except for the conditions in Access Category 1.	MMTEL video
6	All except for the conditions in Access Category 1.	SMS
7	All except for the conditions in Access Category 1.	MO data that do not belong to any other Access Categories (NOTE 4)
8	All except for the conditions in Access Category 1	MO signalling on RRC level resulting from other than paging
9-31		Reserved standardized Access Categories
32-63 (NOTE 2)	All	Based on operator classification

NOTE 1: The barring parameter for Access Category 1 is accompanied with information that define whether Access Category applies to UEs within one of the following categories:
a) UEs that are configured for delay tolerant service;
b) UEs that are configured for delay tolerant service and are neither in their HPLMN nor in a PLMN that is equivalent to it;
c) UEs that are configured for delay tolerant service and are neither in the PLMN listed as most preferred PLMN of the country where the UE is roaming in the operator-defined PLMN selector list on the SIM/USIM, nor in their HPLMN nor in a PLMN that is equivalent to their HPLMN.
When a UE is configured for EAB, the UE is also configured for delay tolerant service. In case a UE is configured both for EAB and for EAB override, when upper layer indicates to override Access Category 1, then Access Category 1 is not applicable.

NOTE 2: When there are an Access Category based on operator classification and a standardized Access Category to both of which an access attempt can be categorized, and the standardized Access Category is neither 0 nor 2, the UE applies the Access Category based on operator classification. When there are an Access Category based on operator classification and a standardized Access Category to both of which an access attempt can be categorized, and the standardized Access Category is 0 or 2, the UE

For Radisys's implementation perspective , we can focus on below model (if not in 2022) for 5G accessibility differentiation and control framework. Access requests coming to a given gNB either from a CPE, the CN, or other RAN nodes (gNBs), can be selectively blocked by the activation of different mechanisms in ORAN, each leveraging the available information about the request type and prioritization indicators. If a CPE tries to make an attach with Establishment Cause which is classified as AC/AI as stated above and when such CPE performs random access procedure for initial access, which indicates the reason for its access request. To support early identification of prioritized services, or access restriction enforcement; like IMS-based video calls, UHD subscribers, a set of new establishment causes, including mo-VideoCall, mps-PriorityAccess and mcs-PriorityAccess, has been added in NR to those already supported in LTE, like emergency and highPriorityAccess. By receiving the establishment cause at the CBRA procedure, the network can identify the priority of the associated request and decide whether to accept it, and send an RRC Setup message to the CPE, or to reject it, and send an RRC Reject message.

Please note that there is dependency on CPE support and MNO's willingness to support this. Still TBC to consider for 1st launch.