Cairo University
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Capacity Optimization

for Cellular Networks

(4G & 3G)

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Agenda

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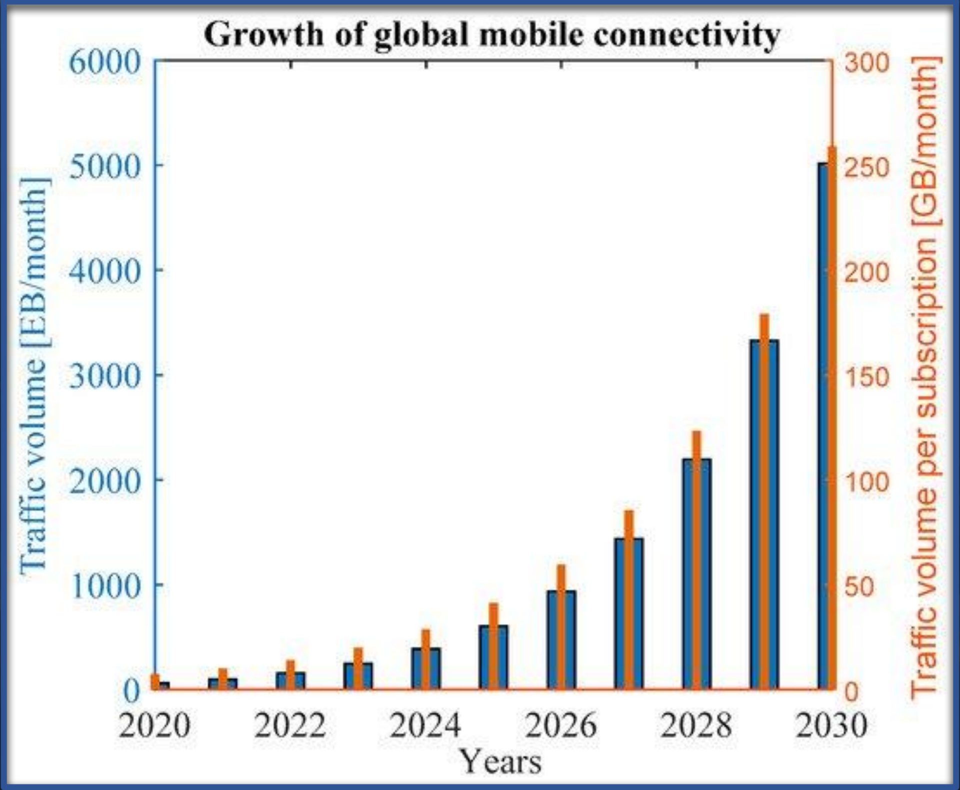
4. **Capacity Optimization for 3G Network**
   4.1. Monitor 3G KPIs
   4.2. Detect 3G Capacity Problems
   4.3. Solve 3G Capacity Problems

Why Optimization ?!

During the past few decades wireless technology has seen a tremendous growth. The recent introduction of high-end mobile devices has further increased subscribers' demand for high bandwidth, Network optimization results and the level of network optimization work, directly related to the future performance of the network stability and capacity. When doing optimization, the following performance must be considered:

- ➔ Coverage
- ➔ Interference
- ➔ Mobility
- ➔ Capacity
- ➔ Quality



Machine Learning

K-MEANS Clustering

Elbow Method

K-MEANS Clustering

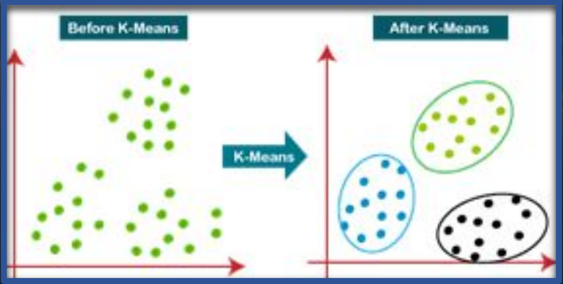
An algorithm for partitioning (or clustering) N data points into K disjoint subsets containing data points so as to minimize (WCSS) Within Cluster Sum of Squares which defines the total variations within a cluster.

$$WCSS = \sum_{j=1}^{k} \sum_{i:S_i=j} |x_i - \mu_j|^2$$

Where X_i is a vector representing the i_{th} data point and M_j is the geometric centroid of the data points in S_j.

It divides the data into clusters by satisfying these two requirements:

- **Each group should consist of at least one point.**
- **Each point must belong to exactly one group.**



K-MEANS Clustering Steps

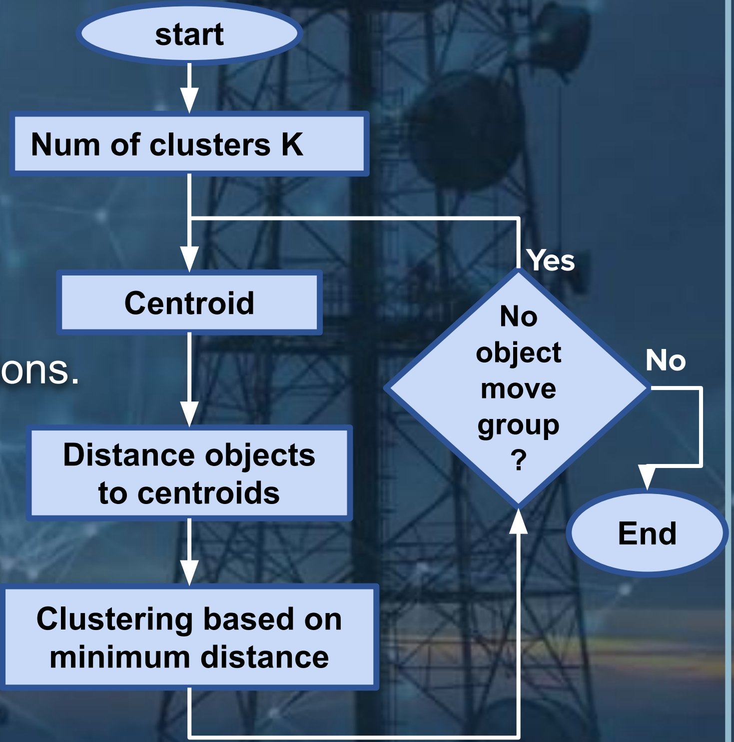
1. Initialize cluster centers.
2. Assign observations to closest cluster center.

$$S_i \leftarrow \boldsymbol{argmin}_j ||\boldsymbol{\mu}_j - \boldsymbol{x}_i||^2$$

3. Revise cluster centers as mean of assigned observations.

$$\boldsymbol{\mu}_j \leftarrow \boldsymbol{argmin}_\mu \sum_{i:S_i=j} ||\boldsymbol{\mu} - \boldsymbol{x}_i||^2$$

4. Repeat (1) and (2).until convergence to Local optimum



Elbow-Method

The Elbow method is one of the most popular ways to find the optimal number of clusters. This method uses the concept of WCSS value.

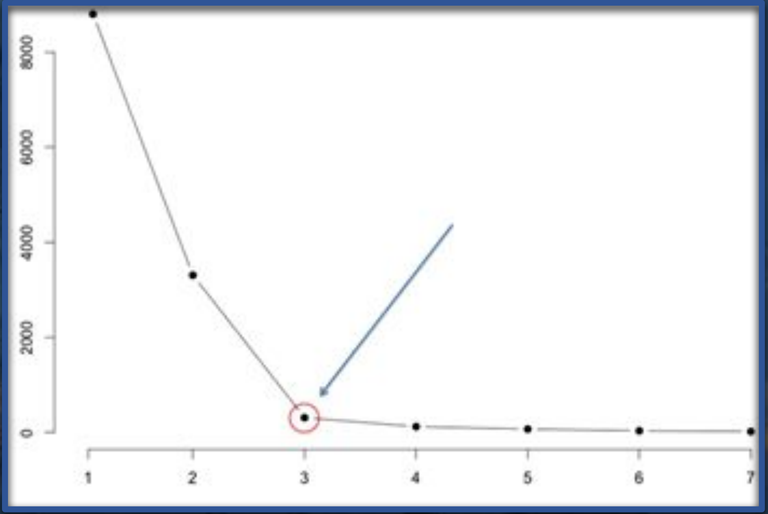
Steps:

1. It executes the K-means clustering on a given dataset for different K values (ranges from 1-10).

2. For each value of K, calculates the WCSS value.

3. Plots a curve between calculated **WCSS** values and the number of clusters K.

4. The sharp point of bend or a point of the plot looks like an arm, then that point is considered as the best value of K.



Capacity Optimization

for 4G Network

1- Monitor 4G KPIs

2- Detect Capacity Problems

3- Solve Capacity Problems

1- Monitor 4G KPIs

KPIs for 4G

In Optimization process, the KPIs used to monitor and optimize the radio network performance to provide better subscriber quality or to achieve better use of installed network resources.

LTE KPIs

Radio Network KPIs
Focus in radio network performance

Service KPIs
Focus on the user experience

Service KPIs:

Latency KPI	- Access latency. - Service latency. - Interrupt latency.
Integrity KPI	- Service UL / DL throughput.

KPIs for LTE RAN (Radio Access Network):

LTE-KPIs	INDICATORS
Accessibility KPI	- RRC Setup Success Rate. - ERAB Setup Success Rate. - Call Setup Success Rate. Used to measure whether the services requested by users in a particular situation can be accessed correctly, and also indicates the quality of availability when users need it.
Retainability KPI	- Service Call Drop Rate. - Call Drop Rate. Used to measure how the network able to hold and provide the services for the users.
Mobility KPI	- Intra-Frequency HO. - Inter-Frequency HO. - Inter-RAT HO. Used to measure the performance of network which can handle the movement of users and still retain the service for the user.
Integrity KPI	- E-UTRAN IP Throughput. - IP Throughput in DL. - E-UTRAN IP Latency. Used to measure the honesty of network to its user, such as what is the throughput, latency which users were served.
Availability KPI	- E-UTRAN Cell Availability. - Partial cell availability. Used to measure how the network able to hold and provide the services for the users.
Utilization KPI	- Mean Active Dedicated EPS Bearer Utilization. Used to evaluate utilization performance of EPC network.

2- Detection of 4G Capacity Problems

We executed our Algorithms using **HUAWEI VENDOR Counters**

2.1- E-UTRAN Average CQI

2.2- Service Drop Rate

2.3- Overshooting Cells

2.4- High Utilization

2.5- Unbalanced Cells

2.6- Throughput

2.7- Traffic-Volume with CCE-Usage

2.1- E-UTRAN Avg CQI

In the LTE system, Channel Quality Indicator is used by the UE to indicate the channel quality to the eNB and then indicate the level of modulation and coding the UE could operate.

In our work, we calculated E-UTRAN Average-CQI to classify the cells according to the quality of each of them as per the following illustration:

E-UTRAN Average CQI = A / B

There are 15 different CQI values and these values mapping between CQI and modulation

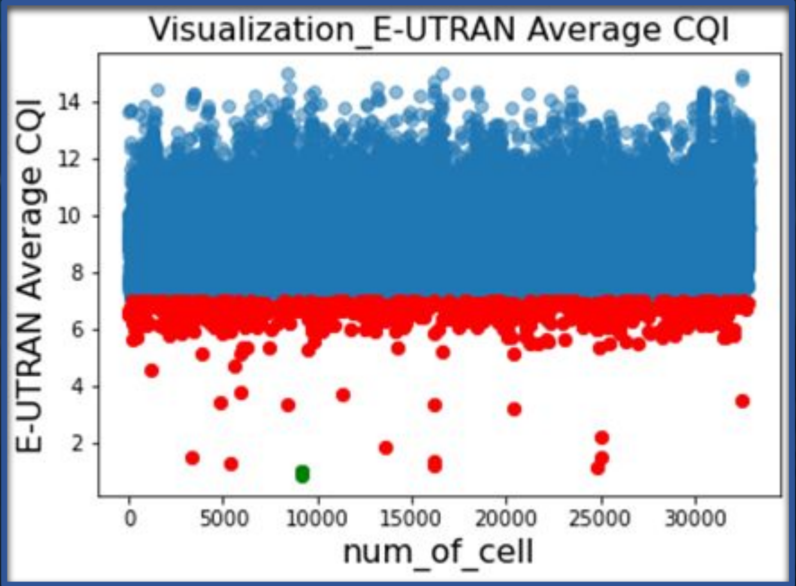
Where:

$$A = [L.ChMeas.CQI.DL.0]*0 + [L.ChMeas.CQI.DL.1]*1 + [L.ChMeas.CQI.DL.2]*2 + [L.ChMeas.CQI.DL.3]*3 + [L.ChMeas.CQI.DL.4]*4 + [L.ChMeas.CQI.DL.5]*5 + [L.ChMeas.CQI.DL.6]*6 + [L.ChMeas.CQI.DL.7]*7 + [L.ChMeas.CQI.DL.8]*8 + [L.ChMeas.CQI.DL.9]*9 + [L.ChMeas.CQI.DL.10]*10 + [L.ChMeas.CQI.DL.11]*11 + [L.ChMeas.CQI.DL.12]*12 + [L.ChMeas.CQI.DL.13]*13 + [L.ChMeas.CQI.DL.14]*14 + [L.ChMeas.CQI.DL.15]*15)$$

$$B = ([L.ChMeas.CQI.DL.0] + [L.ChMeas.CQI.DL.1] + [L.ChMeas.CQI.DL.2] + [L.ChMeas.CQI.DL.3] + [L.ChMeas.CQI.DL.4] + [L.ChMeas.CQI.DL.5] + [L.ChMeas.CQI.DL.6] + [L.ChMeas.CQI.DL.7] + [L.ChMeas.CQI.DL.8] + [L.ChMeas.CQI.DL.9] + [L.ChMeas.CQI.DL.10] + [L.ChMeas.CQI.DL.11] + [L.ChMeas.CQI.DL.12] + [L.ChMeas.CQI.DL.13] + [L.ChMeas.CQI.DL.14] + [L.ChMeas.CQI.DL.15])$$

Results of Avg-CQI

E-UTRAN Avg-CQI value	From 0 to 1	From 1 to 7	Greater than 7
indication	Poorest Channel Quality	Poor Channel Quality	Accepted Quality
Number of Cells	3	793	32080



2.2- Service Drop Rate

In our work we used Service Drop Rate KPI can be used to evaluate the call drop rate of all services, including VoIP service as the following illustration.

Formula used to calculate Service Drop Rate KPI:

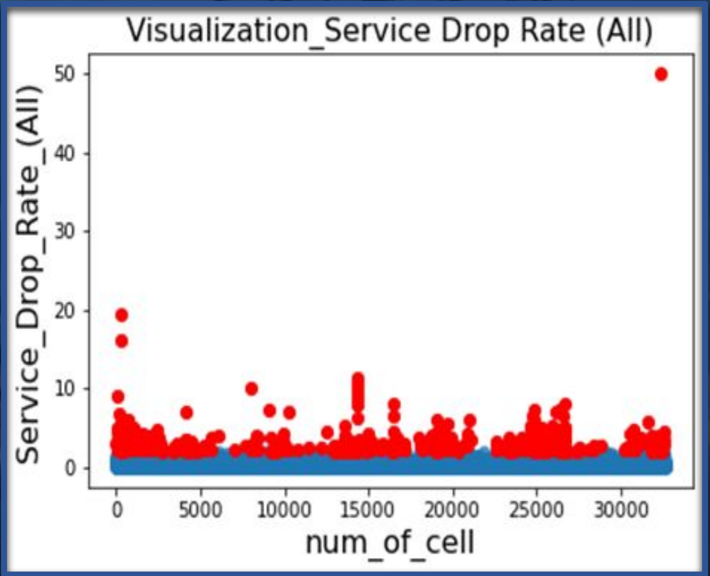
Service Drop Rate = (*A* / *B*)*100

Where:
A=[L.E-RAB.AbnormRel]
B=([L.E-RAB.AbnormRel] + [L.E-RAB.NormRel])

L.E-RAB.AbnormRel	Total number of abnormal E-RAB releases by the eNodeB
L.E-RAB.NormRel	Total number of normal E-RAB releases by the eNodeB

Results:

Service Drop Rate value	Less than 2 %	Greater than 2 %
indication	Accepted Service Drop Rate	high Service Drop Rate
Number of Cells	32112	561



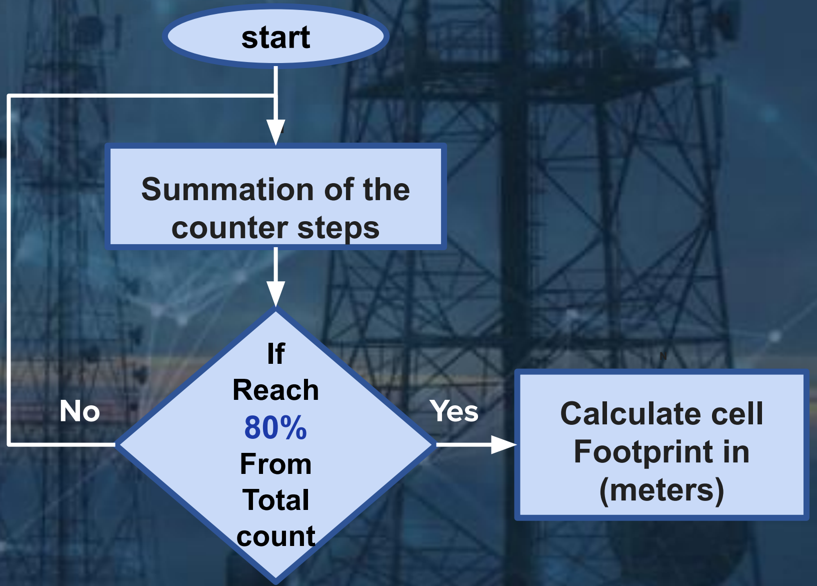
2.3- Detection Overshooting Cells

We use Huawei 4G TA Counters to get footprint of each cell, Once we calculate the footprint, we will use two techniques to detect overshooting.

Table of Counters

Counter name	Distance (m)
L.RA.TA.UE.Index0	0_156
L.RA.TA.UE.Index1	156_312
L.RA.TA.UE.Index2	312_624
L.RA.TA.UE.Index3	624_1092
L.RA.TA.UE.Index4	1092_2028
L.RA.TA.UE.Index5	2028_3588
L.RA.TA.UE.Index6	3588_6630
L.RA.TA.UE.Index7	6708_14508
L.RA.TA.UE.Index8	14508_30108
L.RA.TA.UE.Index9	30108_53508
L.RA.TA.UE.Index10	53508_76908
L.RA.TA.UE.Index11	≥76908

Algorithm to get Cell Footprint



Techniques to detect Overshooting Cells

THE FIRST TECHNIQUE: is depending on comparing the cell's footprint with threshold which depending on type of cell (Rural or Dense), the Rural cell's footprint is compared with 5Km and the dense cell's footprint is compared with 1Km.

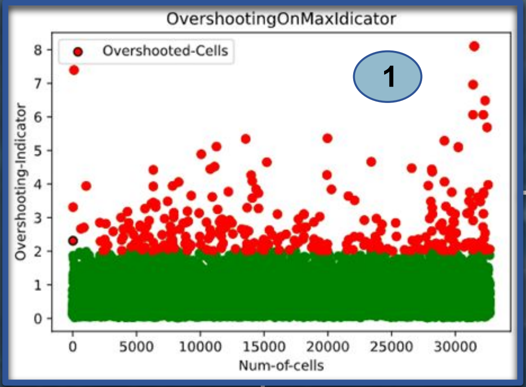
THE SECOND TECHNIQUE is depending on calculating the overshooting indicator which consists of two parameters and compare it with threshold equal two.

$$Overshooting\ Indicator = \frac{Footprint\ of\ cell}{Average\ Site\ to\ Site\ distance}$$

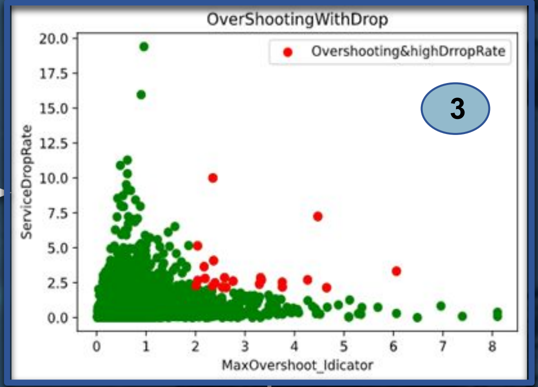
The first parameter is the footprint of specific cell.
The second parameter is the average site to site distance that calculated from neighbour list by calculating the distance between the site and each neighbour and then average the calculated values.

We can take decision of overshooting on cells which have indicator larger than or equal two. We will depend on this technique in our results.

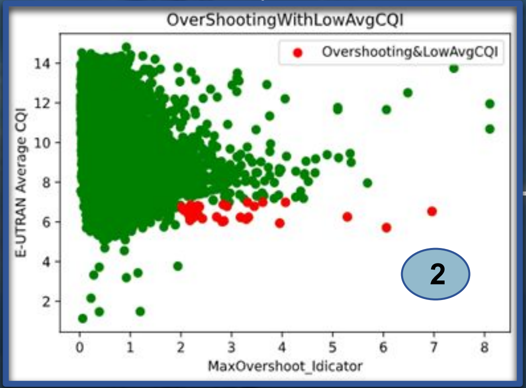
Result of Overshooting Cells



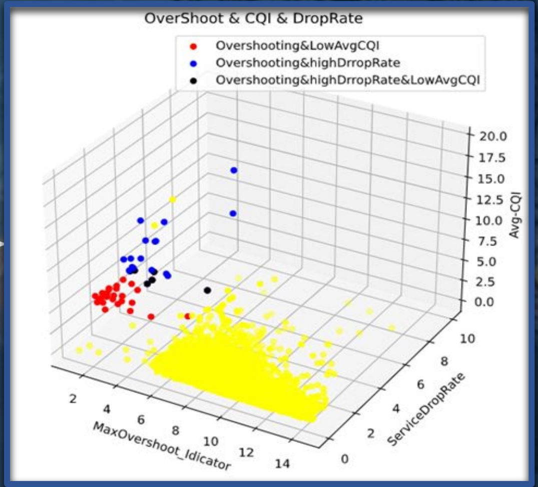
Intersection between overshooting and High-Service Drop Rate



Intersection between overshooting and Low-Avg CQI



Intersection between figure 2&3



Results:

6 Cells have

1. Overshooting. Which mean (MAX Overshooting Indicator >= 2)
2. Low Avg-CQI. Which mean (E-UTRAN Average CQI < 7)
3. High Service Drop Rate. Which mean (Service drop rate >2%)

Cell Name	MaxOvershoot_Idicator	ServiceDropRate	E-UTRAN Average CQI
[illegible]	2.044592469	2.6593	6.624839371
[illegible]	2.19325813	2.8028	6.57531195
[illegible]	3.315962699	2.856	6.981126869
[illegible]	3.290168953	2.3967	6.139977372
[illegible]	3.333946135	2.6898	6.239125178
[illegible]	6.061922868	3.3278	5.70985116

2.4- Detection of Highly Utilized Cells

We detected the Highly utilized Cells by Monitoring the utilization of Physical Resource Block (PRB) and Control Channel Element (CCE).

- Physical Resource Block (PRB) is the minimum unit for resource allocation used for the data transmission in physical layer, Growing traffic leads to a big increase in PRB usage. When the PRB usage approaches to 100%, user rates will decrease which leads to:
  - New UEs may fail to be admitted
  - Admitted users experience is affected

- Control Channel Element (CCE) is a group of resources which is used to send a PDCCH. In each radio frame CCEs is allocated to uplink and downlink UEs to be scheduled and common control signaling.
  When PDCCH symbols are insufficient, UEs may fail to be scheduled as CCEs miss to be allocated to UEs which leads to:
  - long service delay
  - unsatisfactory user experience.

(UL & DL PRB) and CCE Utilization

We used counters to calculate (UL & DL RAB) utilization and CCE Utilization having a threshold of 70% for accepted utilization as the following:

Calculation of of PRB-Utilization

UL PRB Utilization=

$$\frac{L.ChMeas.PRB.UL.Used.Avg}{L.ChMeas.PRB.UL.Avail} * 100\ \%$$

DL PRB Utilization=

$$\frac{L.ChMeas.PRB.DL.UsedAvg}{L.ChMeas.PRB.DL.Avail} * 100\ \%$$

If UL/DL PRB Utilization >70%

Yes

User may be failed in admission OR poor user experience

Calculation of CCE-Utilization

CCE Utilization OR CCE-Usage =

$$\frac{L.ChMeas.CCE.CommUsed + L.ChMeas.CCE.ULUsed + L.ChMeas.CCE.DLUsed}{L.ChMeas.CCE.Avail} * 100\ \%$$

Monitoring **Control channel element** for **PDCCH** Resource Usage.

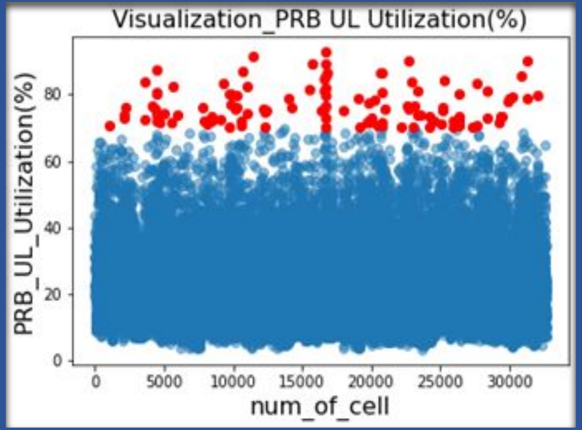
If CCE Utilization >70%

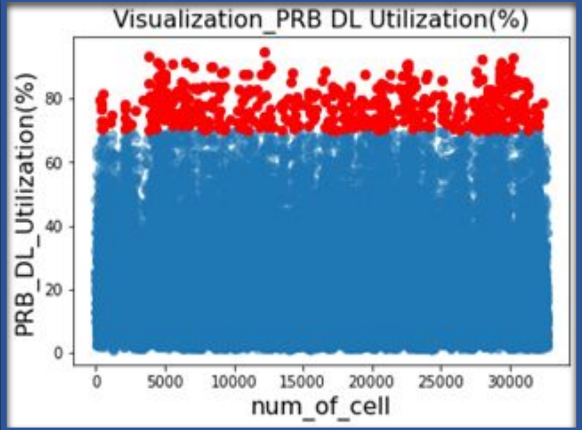
Yes

Scheduling delayed OR poor user experience

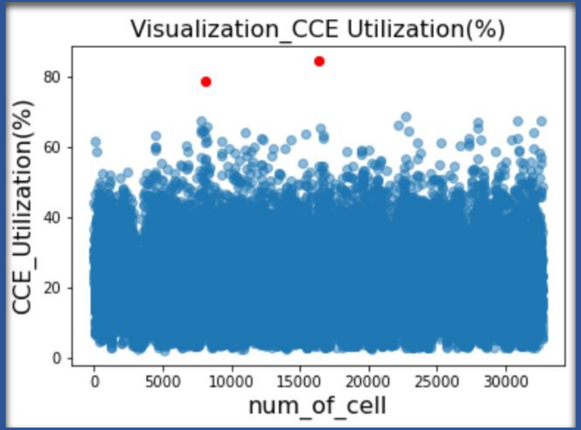
Results of Monitoring

UL & DL PRB Utilization(%)





CCE Utilization(%)



Resource block utilization	Number of Highly Utilized cells	Number of Normally Utilized cells
PRB UL Utilization	113	32560
PRB DL Utilization	527	32146

Control channel element for PDCCH	Number of Highly Utilized cells	Number of Normally Utilized cells
CCE Utilization	2	32671

Results:

Cells With Very Poor Service

After applying KPIs' thresholds, The results showed **cells with a very poor service** as they had High UL/DL PRB utilization (>70%), low average CQI (< 7) and High Service Drop Rate (>2%)

Cell_Name	PRB_UL_Utilization(%)	Service_Drop_Rate_(All)	E-UTRAN Average CQI
[illegible]	87.346	3.1156	6.493247
[illegible]	79.5223	2.1891	6.695075

Cell_Name	(Voda)_PRB_DL_Utilization(%)	Service_Drop_Rate_(All)	E-UTRAN Average CQI
[illegible]	71.801	2.1891	6.695075

The poor service in these cells is a result of the **high congestion** on them.

2.5- Detection Unbalanced Cells

The unbalancing problem mainly appears if there is a difference between the utilization on specific sector's bands (2100, 1800, 900); to detect the unbalanced sectors in specific Enode-B.

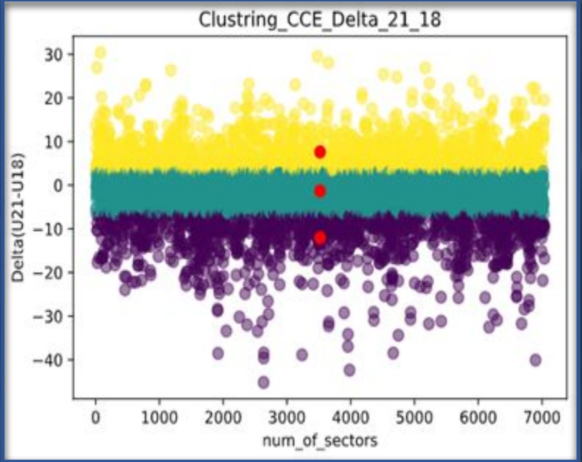
- ➢ **The Algorithm** considers the band (2100) as a reference and then gets the difference between the (2100 and 1800) bands and the (2100 and 900) bands.
- ➢ **The K-means algorithm** is used to detect the unbalanced sectors by clustering deltas between bands to get the unbalanced cells relative to the network status and not by fixing a certain threshold.

- ❖ We have three parameters CCE-Utilization(%), PRB-DL-Utilization(%) and PRB-UL-Utilization(%).

Results of Unbalanced Cells

Clustering Deltas between bands 21&18:

Delta CCE-Utilization(%)

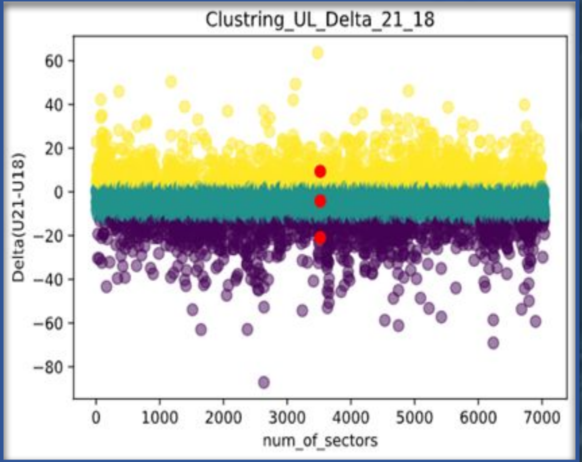


Cluster No.	1	2	3
Center	-12.03145241	-1.31449748	7.6035536
Number of sectors	1258	4116	1664

1258 unbalanced sectors in Band 18

1664 unbalanced sectors in Band 21

Delta PRB-UL-Utilization (%)

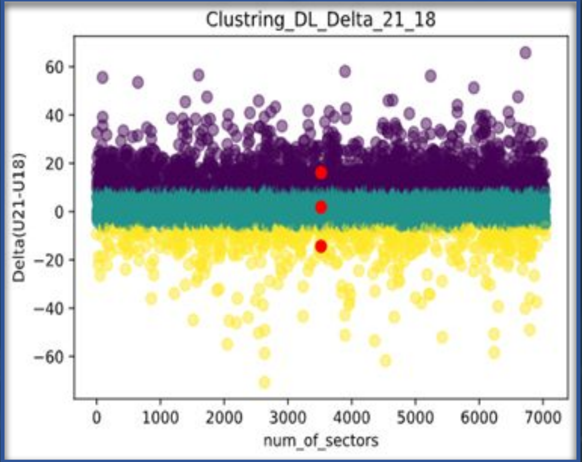


Cluster No.	1	2	3
Center	-20.98655046	-4.14996497	9.36870174
Number of sectors	987	4540	1511

987 unbalanced sectors in Band 18

1511 unbalanced sectors in Band 21

Delta PRB-DL_Utilization(%)



Cluster No.	1	2	3
Center	16.13991177	1.85978152	-14.37462542
Number of sectors	1992	4450	596

596 unbalanced sectors in Band 18

1992 unbalanced sectors in Band 21

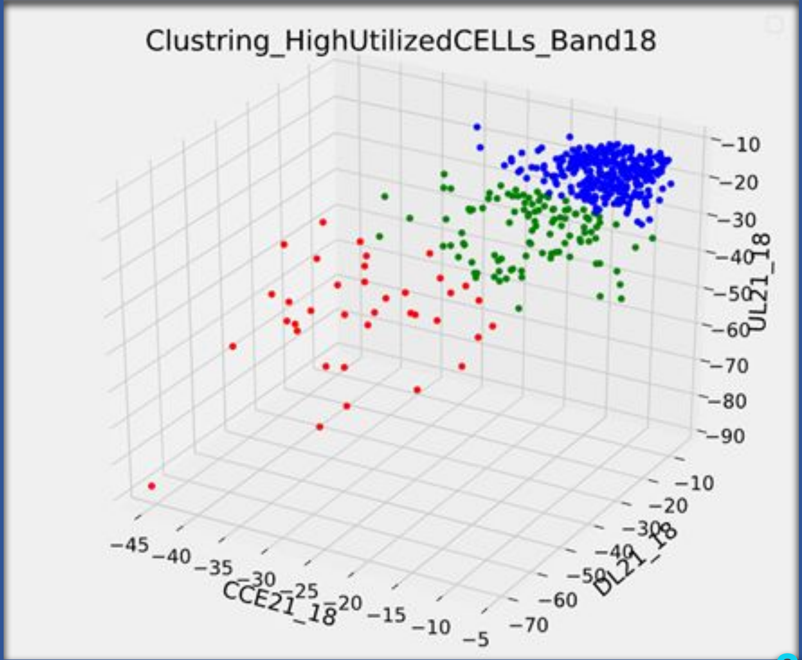
High utilized cells in band18

By intersecting the 3 clusters which have high utilization in Band 18, we will get the common cells which have a high utilization in the three parameters (CCE, DL, UL), which their count is 443 cells. After that we will cluster them again to get the most unbalanced cluster in band18.

Result:

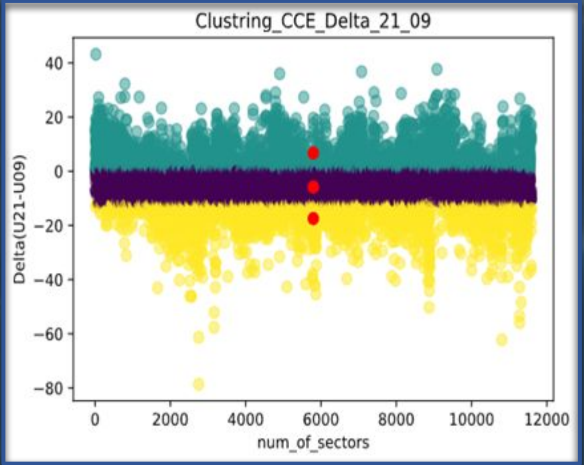
Cluster 1 is the most unbalanced cluster in band18 due to highly negative Deltas and the next is cluster 3 .

Num of cluster	1	2	3
Center x y z	 -30.12 -42.7 -48.2	 -12.881 -10.78 -18.62	 -18.24 -20.38 -31.48
Num of sectors	37	296	110



Clustering Deltas between bands 21&09:

Delta CCE-Utilization(%)

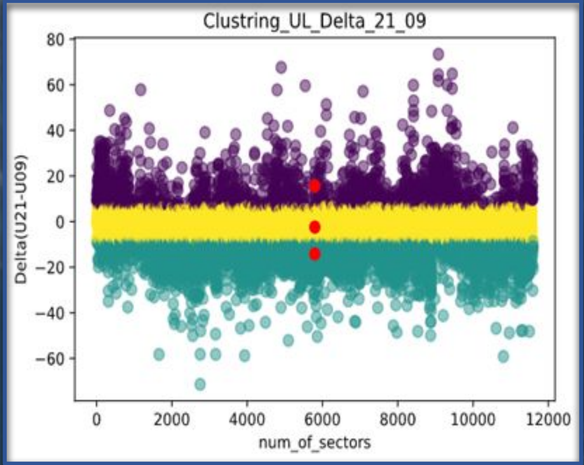


Cluster No.	1	2	3
Center	-5.81655909	6.72723689	-17.45245953
Number of sectors	6238	2985	2372

6238 unbalanced sectors in Band 09

2985 unbalanced sectors in Band 21

Delta PRB-UL-Utilization (%)

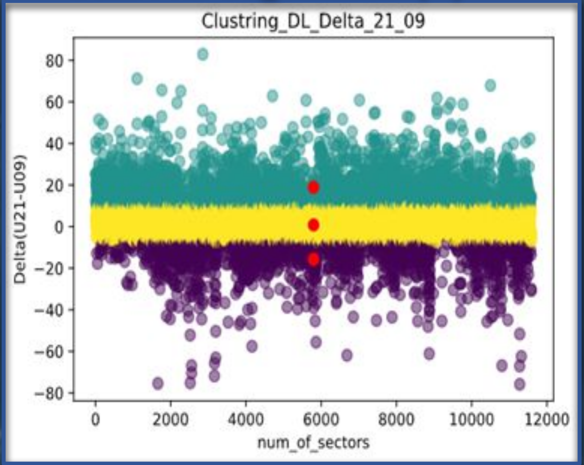


Cluster No.	1	2	3
Center	15.61543469	-14.1770374	-2.43918983
Number of sectors	1417	5402	4776

5402 unbalanced sectors in Band 09

1417 unbalanced sectors in Band 21

Delta PRB-DL_Utilization(%)



Cluster No.	1	2	3
Center	-15.73935892	18.94394137	0.81066827
Number of sectors	1563	3011	7021

1563 unbalanced sectors in Band 09

3011 unbalanced sectors in Band 21

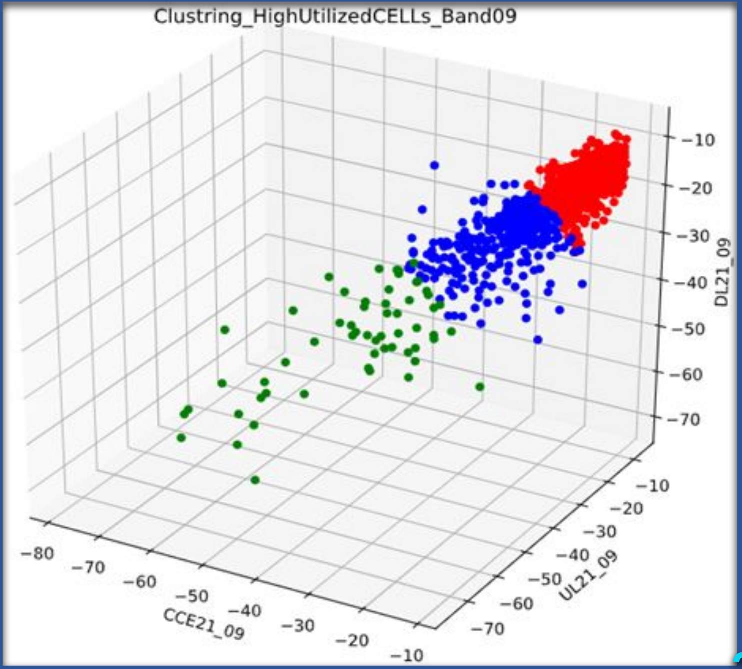
High utilized cells in band09

By intersecting the 3 clusters which have high utilization in Band 09, we will get the common cells which have a high utilization in the three parameters (CCE, DL, UL), which their count is 1387 cells. After that we will cluster them again to get the most unbalanced cluster in band09.

Result:

Cluster 3 is the most unbalanced cluster in band09 due to highly negative Deltas and the next is Cluster 2.

Num of cluster	1	2	3
Center			
x	-16.5	-25.25	-40.175
y	-17.225	-26.373	-41.25
z	-12.035	-24.19	-47.78
Num of sectors	992	337	58

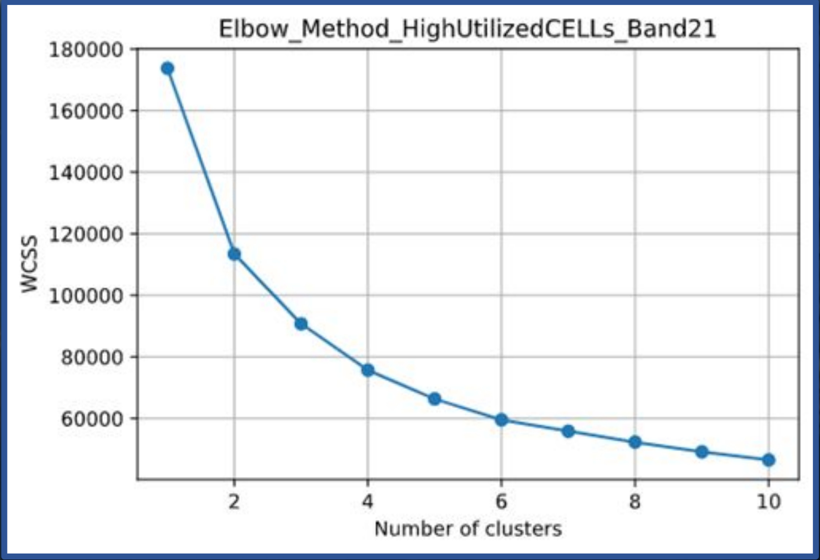


High utilized cells in band21 Caused by (band 18,09)

By intersecting the first 6 clusters, we will get the common cells which have a high utilization in Band21, caused by the unbalancing between bands which band18 and band09 caused it, which their count is 400 cells. After that we will cluster them again to get the most unbalanced cluster in band21.

Result:

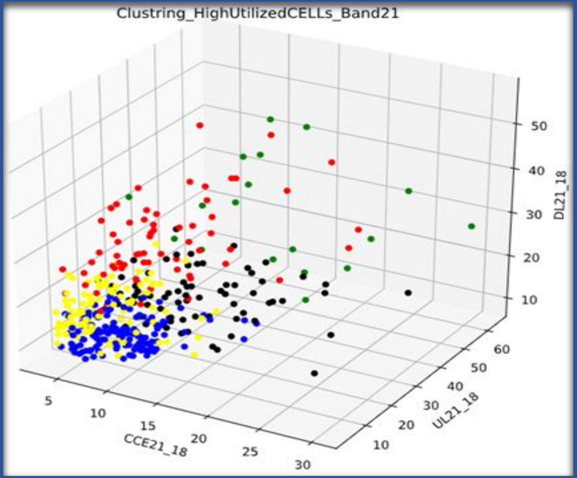
➔ We made 5 clusters to be able to get the most unbalanced cells in band 21 caused by bands 18 & 09.

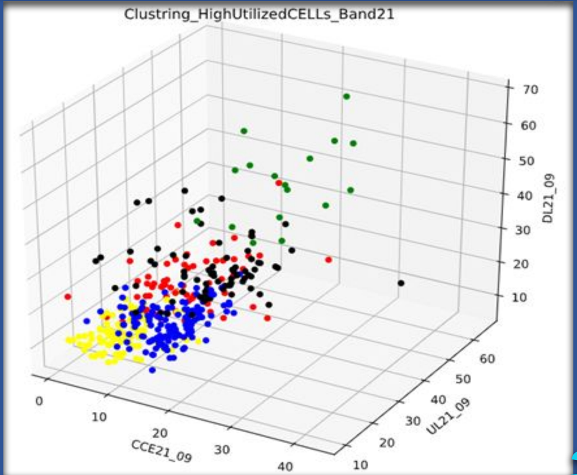


Results:

Cluster number	Centers						Number of cells
	Fig()			Fig()			
	X	Z	Y	X	Z	Y	
	[CCE21_18	DL21_18	UL21_18	CCE21_09	DL21_09	UL21_09]	
1	10.65	31.86	17.74	10.078	18.023	34.048	63
2	8.48	13.32	10.16	15.5	19.6	16.23	77
3	16.89	33.588	38.011	23.83	49.754	38.61	20
4	6.98	17.86	9.75	6.9	10.78	19.35	106
5	12.75	19.14	21.3	19.26	32.44	23.177	134

❖ We note that cluster 3 contains the most unbalanced cell in band21, which band18 and band09 are caused it.





2.6- DL & UL User Throughput

Counters:

L.Thrp.bits.DL : indicates the total throughput of downlink data transmitted at the PDCP layer in a cell.
L.Thrp.Time.DL : indicates the duration for transmitting downlink data at the PDCP layer in a cell.
L.Thrp.bits.UL : indicates the total throughput of uplink data transmitted at the PDCP layer in a cell.
L.Thrp.Time.UL : indicates the duration for transmitting uplink data at the PDCP layer in a cell.

Monitoring Method:

DL User Throughput= L.Thrp.bits.DL / L.Thrp.Time.DL / 1000
UL User Throughput= L.Thrp.bits.UL / L.Thrp.Time.UL / 1000

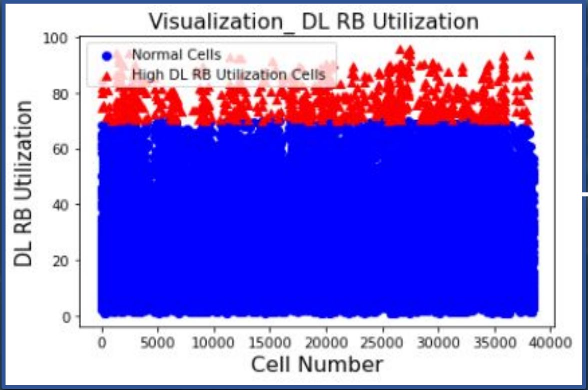
Monitoring threshold:

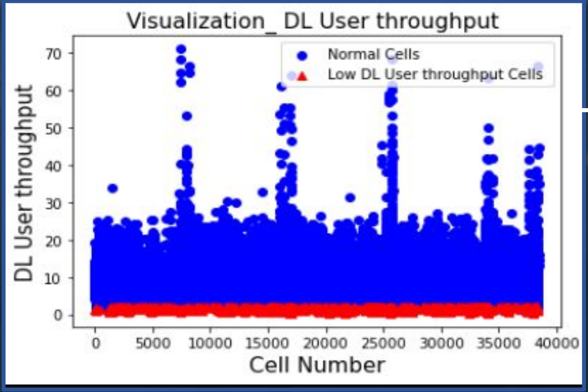
DL User Throughput threshold=2Mbps
UL User Throughput threshold=512Kbps

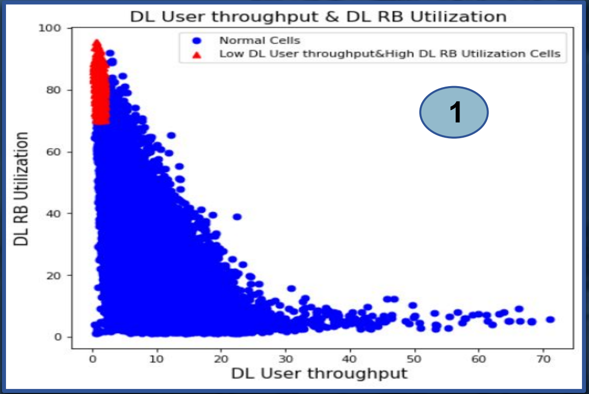
- **We found that 1257 cells have Low DL User Throughput whose DL User Throughput lies below threshold (2Mbps).**
- **We found that 2155 cells have Low UL User Throughput whose UL User Throughput lies below threshold (512Kbps).**

Throughput with RB Utilization

In DL





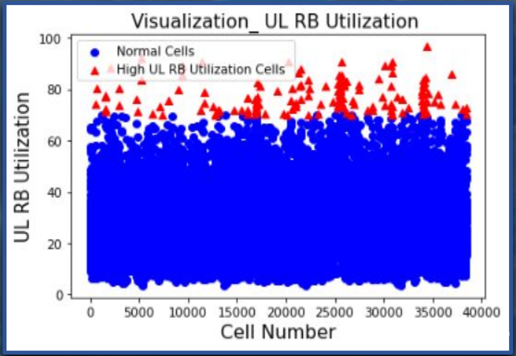


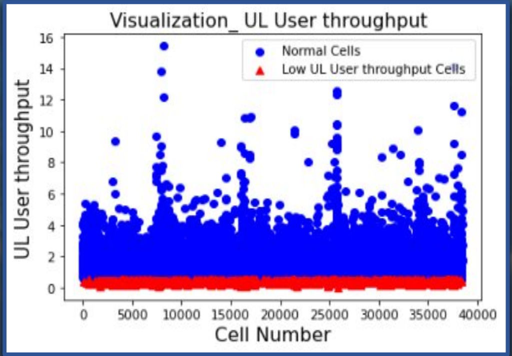
Intersection between DL RB Utilization & DL User Throughput

Number of Normal Cells	Number of Low DL User throughput & High DL RB Utilization Cells
38020	397

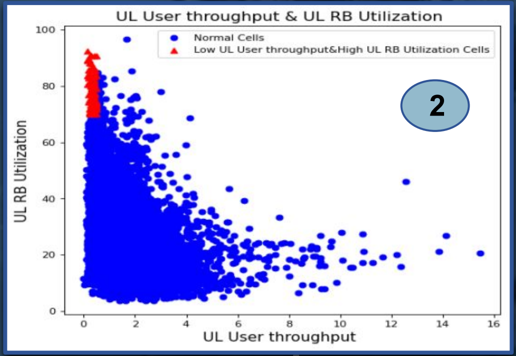
Throughput with RB Utilization

In UL





Intersection between UL RB Utilization & UL User Throughput

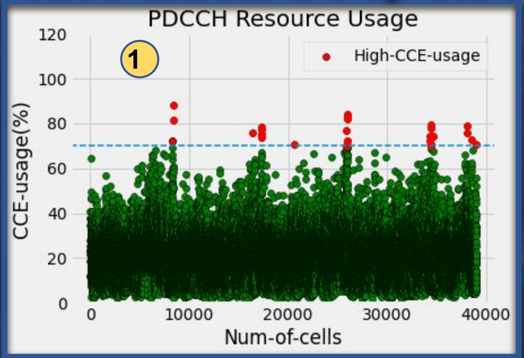


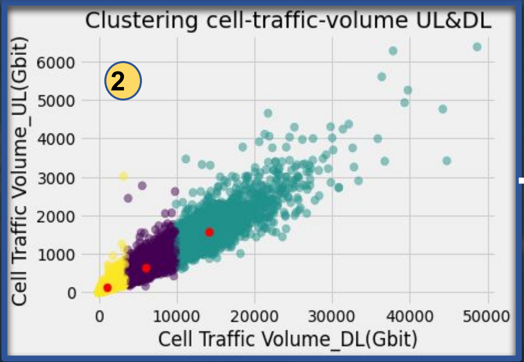
Number of Normal Cells	Number of Low UL User throughput & High UL RB Utilization Cells
38314	103

By intersecting fig(1 & 2), we found that there are 38 cells suffer from Low-User-throughput & High-RB-Utilization in both UL & DL. Impact of Low DL/UL User throughput & High DL/UL RB Utilization: → User may failed in admission or poor user experience. Proposed solution : → 1. Add eNodeB 2. Bandwidth expansion.

2.7- Cell Traffic Volume with CCE-usage

There are 27 cells that have High-CCE-Usage.

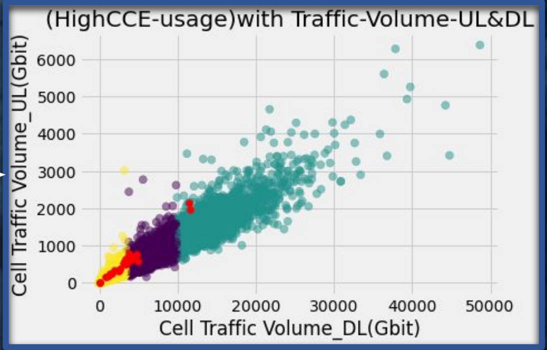




Cluster num	1	2	3
Center x	1140.3	14126.5	5994.7
y	124.4	1591.8	653.7
Num of cells	25195	2135	7276

Cluster 2 contains the cells which have the highest traffic.

Correlation
between
High-CCE-Usage fig(1)
&&
traffic-volume fig (2)



Result:

Cell Name	Cell Traffic Volume_DL(Gbit)	Cell Traffic Volume_UL(Gbit)	CCE_usage	num_cluster
[redacted]	3715.0593	701.7996	77.893977	1
[redacted]	4909.9746	572.2965	75.575528	1
[redacted]	4697.7862	764.2355	75.214061	1
[redacted]	4020.2267	622.756	72.303998	1
[redacted]	4193.3803	706.5103	72.069099	
[redacted]	3778.3367	798.9726	70.6448	
[redacted]	3545.0375	603.7678	70.086068	
[redacted]	11417.8284	2149.4622	73.995669	2
[redacted]	11570.6242	1958.9015	72.611796	2
[redacted]	0.1859	0.027	88.308726	3
[redacted]	723.9799	167.4888	84.196054	3
[redacted]	1906.1219	336.7136	82.901842	3
[redacted]	3086.6437	536.6968	81.900501	3
[redacted]	0.203	0.0421	81.252677	3
[redacted]	2598.1296	385.9903	79.174584	3
[redacted]	3366.4299	644.584	78.746181	3
[redacted]	2416.5659	355.9684	78.341755	3
[redacted]	2572.1699	371.0545	77.062952	3
[redacted]	3465.0324	538.2925	76.684642	3
[redacted]	3191.3212	596.3068	75.979964	3
[redacted]	982.6474	166.66	74.28088	3
[redacted]	1609.9339	240.1245	73.534826	3
[redacted]	3305.3574	482.6818	72.135466	3
[redacted]	1.2168	0.205	72.021849	3
[redacted]	1223.1232	191.4081	70.852747	3
[redacted]	1316.986	245.3478	70.499183	3
[redacted]	2499.0579	317.8932	70.202774	3

We found that only 2 cells from 27 cells lie in cluster 2 which has the highest traffic.

3- Solve 4G Capacity Problems

3.1- Overshooting Solution

3.2- High Utilization Solution

3.3- Unbalancing Solution

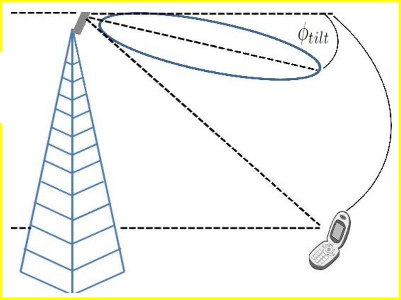
3.1- Overshooting Solution

The **downtilt angle** must be adjusted properly to **ensure network performance**.

because

If Downtilt angle is reduced too much → Overshoot coverage can be easily caused

If Downtilt angle is increased too much → coverage holes can be easily caused



Cell with overshooting coverage

Yes

Adjust the following parameters

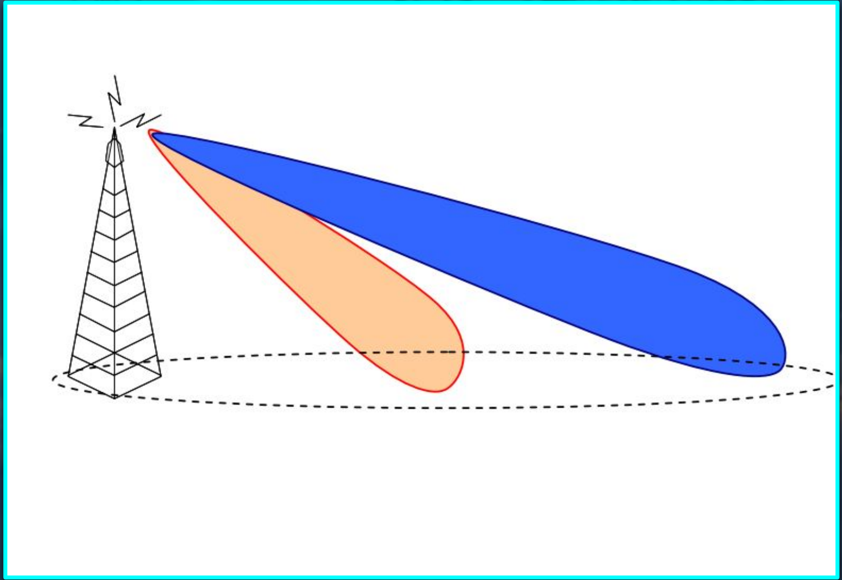
- Downtilt Angle
- Cell Transmit Power
- Antenna Height

If an eNodeB is in a Too High or Low place → serious overshoot coverage or insufficient coverage is caused

3.2- High Utilization Solution
Adaptive Beamforming

Cell splitting using **Beamforming** is a technique of <u>**improving channel capacity**</u> which directly <u>**reduces call blocking probability**</u> and <u>**call delay probability**</u>

Beamforming techniques allow to direct the signal toward the useful users while decreasing at the same time the interference toward and from the users of the neighbouring cells.



There are two types of Beamforming:

1. **Vertical Beamforming**
2. **Horizontal Beamforming**

Our proposed solution is vertical beamforming

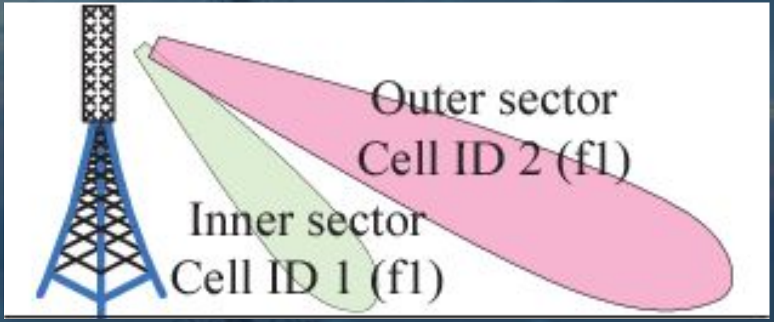
Vertical Sectorization with Same Carrier Frequency:

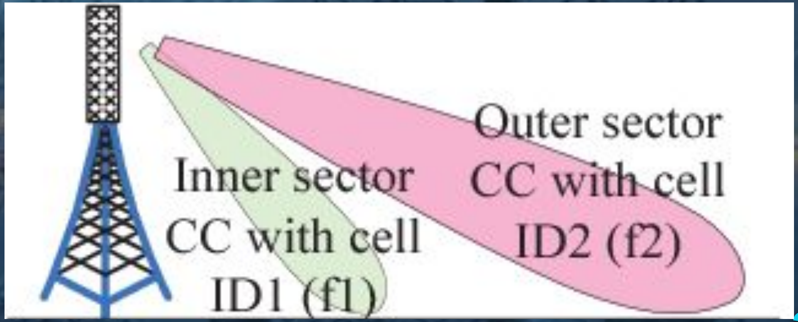
A cell is sectorized into inner sector and outer sector. Same carrier frequencies are used by all sectors in the system. The transmitting power for each vertical sector is halved to maintain the total transmitting power. Each user is associated to the sector with maximal received power.

co-channel interference among the vertical sectors is **unavoidable**.

Vertical Sectorization with Different Carrier Frequency:

Different carrier frequency bands are assigned to the pair of sectors. resulting in **zero co-channel interference** between the inner sector and the outer sector. in this scenario we may use the benefits of the carrier aggregation (CA) framework specified in current LTE systems, by configuring each vertical sector with one carrier component (CC).





3.3- Unbalancing-Solution

Cell Reselection

Intra frequency
or
Equal-Priority
Cell Reselection

→ Move to same frequency in another cell in same technology.

Inter frequency
or
Different-Priority
Cell Reselection

→ Move to different frequency in another cell in same technology.

IRAT
or
Different-Priority
Cell Reselection

→ Move to different frequency in different technology .

- ❖ We focus on Inter frequency (Different-Priority Cell Reselection) to solve unbalancing load between different bands.

Inter frequency (Different-Priority)

Different-priority inter frequency cell can be classified into:

1. Reselection to a lower-priority cell .
2. Reselection to a higher-priority cell.

To lower priority

It will start measurement If

Srxlev< SnonintraSearchP

or

Squal< SnonintraSearchq

When can we do reselection?!!

1. **Srxlev(S) < ThrshServLowlev.**
2. **Srxlev(N) > ThreshXLowlev.**
3. Above two conditions achieved for EutranResetTime.

To higher priority

It measure all time .

When can we do reselection?!!

1. **Srxlev(N) >ThreshXhighlev.**
2. Above condition achieved for EutranResetTime.

SnonIntraSearchP : The threshold of current cell Srxlev to perform inter-frequency.

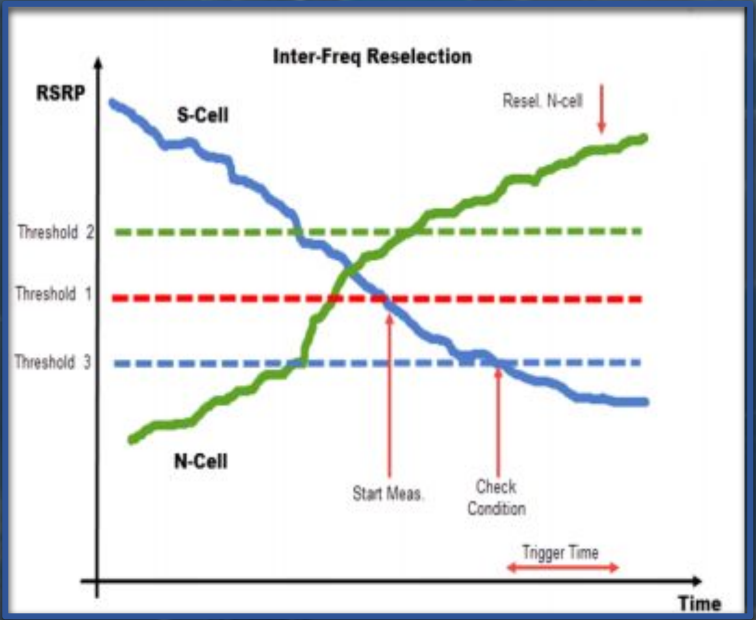
SnonIntraSearchq : The threshold of current cell Squal to perform inter-frequency.

$$Srxlev = Qrxlevmeas - (Qrxlevmin + Qrxlevminoffset) - Pcompensation$$
$$Squal = Qqualmeas - (QQualMin + QQualMinOffset)$$
Where:

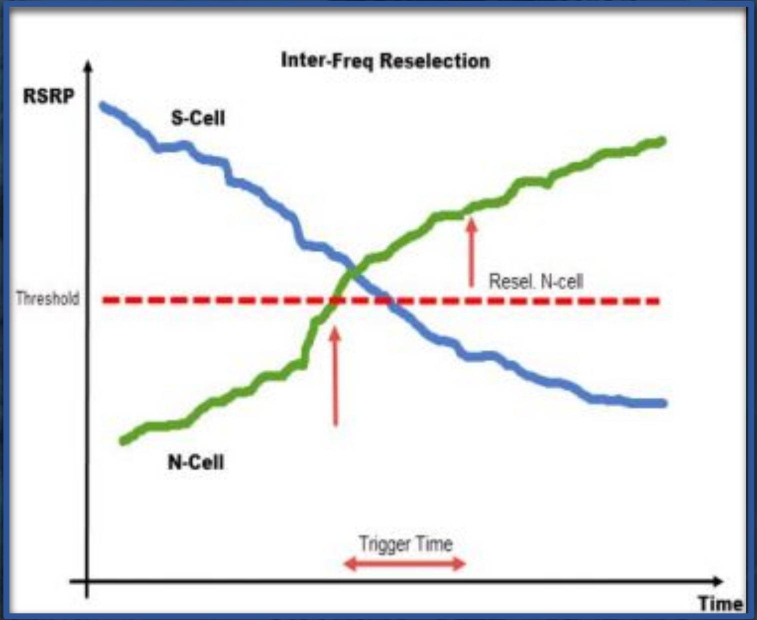
parameter	Description
Qrxlevmeas	Measured RSRP value.
Qrxlevmin	Minimal required Rx level (dbm) in SIB1.
Qrxlevminoffset	The offset to Qrxlevmin. It is broadcast in the SIB1.
Pcompensation	The result of the function: max ($P_{\text{Max allowed power}} - P_{\text{UE Maximum Output Power}}$, 0), $P_{\text{Max allowed power}}$ is sent in SIB1.
Qqualmeas	the measured RX signal quality (RSRQ value) of the cell.
QQualMin	Minimal required signal Quality.
QQualMinOffset	The offset to QqualMin. It is broadcast in the SIB1.

(SIB1)
System **I**nformation **B**lock Type **1**
Which carry information from the network to UE .

Inter-Freq Low Priority Cell Reselection



Inter-Freq High Priority Cell Reselection



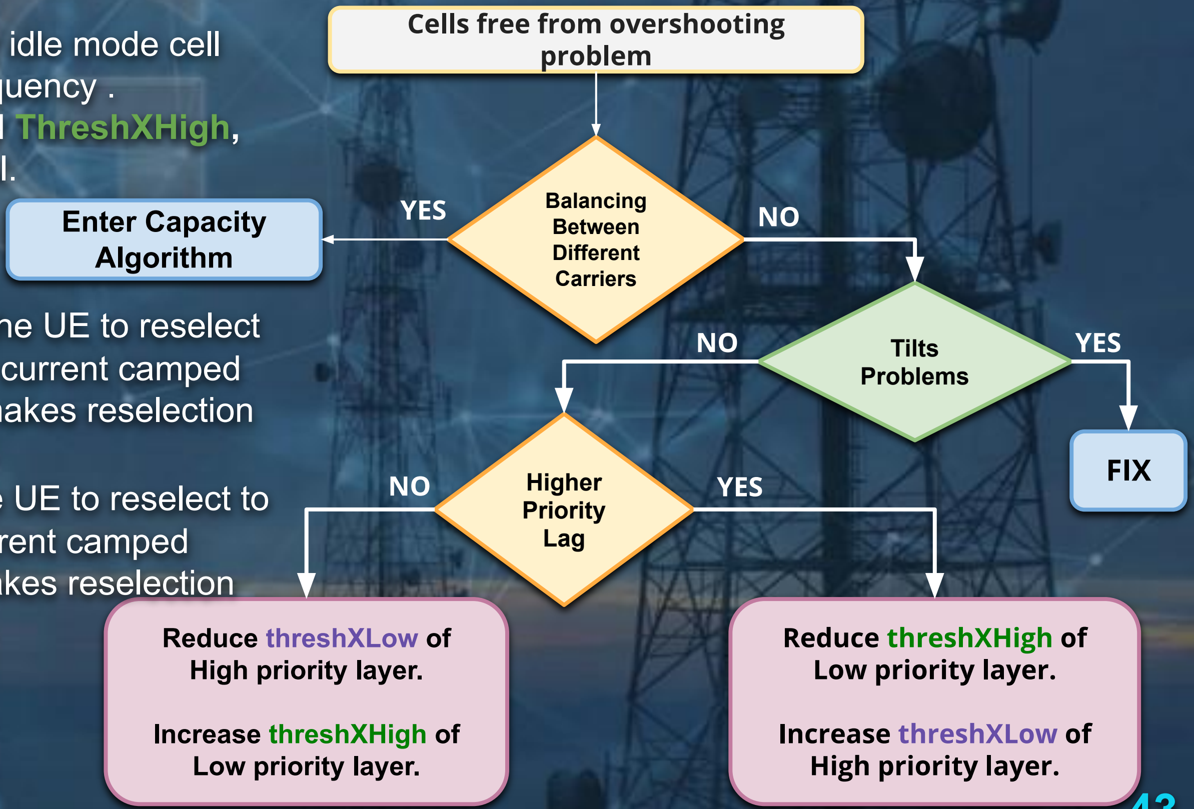
Threshold 1= QRXLevMin - SNonIntraSearch
Threshold 2= QRXLevMin - ThreshXLowlev
Threshold 3= QRXLevMin - ThrshServLowlev

Threshold = QRXLevMin- ThreshXHigh

Unbalanced Cells Solution Algorithm

THRESHX PARAMETERS:

ThreshX parameters are used in LTE for idle mode cell reselection towards a different LTE Frequency .
We have 2 parameters ThreshXlow and ThreshXHigh,
The 2 parameters relate to the target cell.



ThreshXHigh: The threshold used in the UE to reselect to frequency with higher priority than the current camped frequency, (a large ThreshXHigh value makes reselection harder).

ThreshXlow: The threshold used in the UE to reselect to frequency with lower priority than the current camped frequency, (a large ThreshXlow value makes reselection harder).

Capacity Optimization

for 3G Network

1- Monitor 3G KPIs

2- Detect Capacity Problems

3- Solve Capacity Problems

1- Monitor 3G KPIs

KPIs for 3G

KPIs are parameters that are to be observed when the network monitoring is going on.

The main KPIs are monitored for UMTS:

3G-KPIs	INDICATORS
Accessibility KPI	- RRC Setup & Access Rate. - RAB Setup & Access Rate. - Call Setup Success Rate.
Retainability KPI	- RRC Drop Rate. - RAB Drop Rate.
Mobility KPI	- SHO/ISHO Success Rate. - SHO Overhead.
Usage KPI	- Cell Availability. - Cell Throughput.

2- Detection of 3G Capacity Problems

2.1- RRC Attempt Congestion Ratio

2.2- RRC Blocking (due to UL & DL CE)

2.3- RAB Blocking (CS & PS)

2.4- DCCC Failure

2.5- RAB Loss (CS & PS)

2.4- RNC Overload Congestion

We executed our Algorithms using **HUAWEI VENDOR Counters**

Huawei 3G Counters

➢ RRC-Congestion Counters

RRC.FailConnEstab.Cong: Number of RRC Connection Reject due to network

VS.RRC.AttConnEstab.Cell: Number of RRC connection requests

→ Calculate: **RRC Attempt Congestion Ratio**

❖ **We then monitor Failure counters:**

1) **VS.RRC.Rej.UL.CE.Cong:** Cell UL CE resource request failure.
2) **VS.RRC.Rej.DL.CE.Cong:** Cell DL CE resource request failure.
3) **VS.RAB.FailEstCs.ULCE.Cong:** Number of CS RABs unsuccessfully established.
4) **VS.RAB.FailEstPs.ULCE.Cong:** Number of PS RABs unsuccessfully established.
5) **VS.RAC.DCCC.Fail.ULCE.Cong:** Number of failures in the DCCC procedure in UL.
6) **VS.RAC.DCCC.Fail.DLCE.Cong:** Number of failures in the DCCC procedure in DL.

➢ RAB-LOSS Counters

We used:

1) **VS.RAB.Loss.CS.Congstion.CELL:**Number of released RABs due to cell congestion in circuit switch.
2) **VS.RAB.Loss.PS.Congstion.CELL:**Number of released RABs due to cell congestion in Packet switch.

➢ OverLoad Congestion counters

We used:

1) **VS.LCC.OverCongNumUL:** Number of UL Overload Congestions.
2) **VS.LCC.OverCongNumDL:**Number of DL Overload Congestions.

2.1- RRC Attempt Congestion Ratio

RRC Setup Failure Due To congestion one of the most common RRC failure which is present in every network To detect the congestion of RRC Attempt in a cell we calculate an important KPI called RRC Attempt Congestion Ratio using the following formula:

RRC Attempt Congestion Ratio (Cell) = (**A**/**B**)*100%

Where:

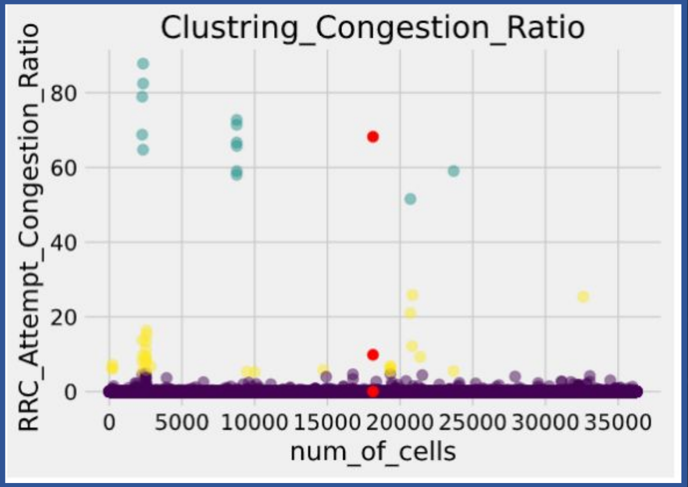
- **A ⟶ RRC.FailConnEstab.Cong: Number of RRC Connection Reject due to network congestion.**
- **B ⟶ VS.RRC.AttConnEstab.Cell: Number of RRC Connection Attempts.**

Results of Monitoring
RRC Attempt Congestion Ratio

After Calculating KPI RRC Attempt Congestion ratio we used K-Means Algorithm to know which has high congestion without using threshold, we note that we have 2 clusters with high congestion.

Cluster 2 is the most congested cluster and the next one is Cluster 3 .

Cluster Num	1	2	3
center	1.91640097	70.9568732	9.84189212
Num of cells	36229	13	31



High RRC Attempt Congestion Ratio Causes

In order to reduce RRC Attempt Congestion Ratio we should detect the reasons of increasing the counter below.

VS.RRC.FailConnEstab.Cong

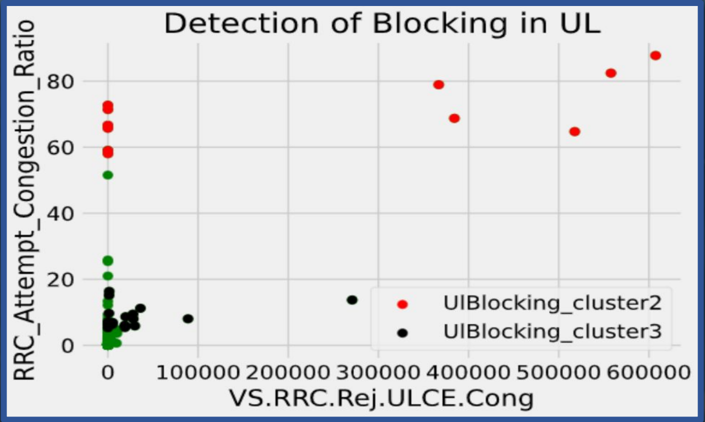
SO, study the value of the counters to check what types of resources are congested.

❖ Check Radio-Congestion by using the Counters below:

- UL Power → VS.RRC.Rej.ULPower.Cong.
- DL Power → VS.RRC.Rej.DLPower.Cong.
- Code → VS.RRC.Rej.Code.Cong.
- UL CE → VS.RRC.Rej.ULCE.Cong.
- DL CE → VS.RRC.Rej.DLCE.Cong.
- UL IUB Bandwidth → VS.RRC.Rej.ULIUBBand.Cong.
- DL IUB Bandwidth → VS.RRC.Rej.DLIUBBand.Cong.

2.2- RRC Blocking
RRC Blocking due to UL CE & Congestion Ratio

The next step is to monitor the RRC Blocking due to Uplink CE in the cells and correlate them with high RRC congestion ratio which is in cluster 2 and cluster 3 which calculated pervious.

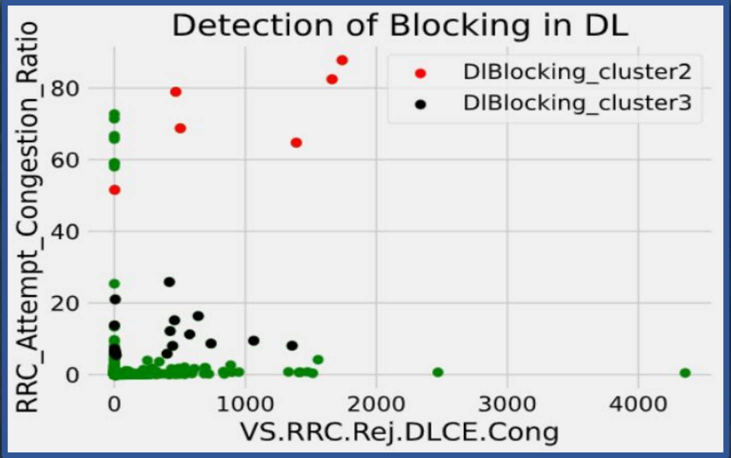


- **Cluster 2 contains 11 cells which has very high Congestion and some of cells suffer from high RRC Blocking due to UL CE.**
- **Cluster 3 contains 18 cells which has very high Congestion and some of cells suffer from high RRC Blocking due to UL CE.**

RRC_Attempt_Congestion_Ratio	VS.RRC.Rej.ULCE.Cc	num_cluster
87.76399106	607451	2
82.44618441	557911	2
78.92917002	366913	2
72.72727273	8	2
71.42857143	90	2
68.75543346	384314	2
66.66666667	4	2
65.75342466	48	2
64.73349016	517779	2
59.01639344	36	2
58.03571429	130	2
16.33902397	1501	3
15.14900233	1294	3
13.73230636	270955	3
11.2260707	36098	3
9.694251936	1188	3
9.455092952	27910	3
8.663464146	19719	3
8.027699301	88898	3
8.006311835	28171	3
7.195308315	1	3
6.899713319	5338	3
6.303327951	1	3
6.298216456	5075	3
6.072717646	18799	3
5.874101084	29916	3
5.814333155	19183	3
5.402911363	18956	3
5.269768458	1	3

RRC Blocking due to DL CE & Congestion Ratio

The next step was to monitor the RRC Blocking due to Downlink CE in the cells and correlate them with high RRC congestion ratio which is in cluster 2 and cluster 3 which calculated pervious.

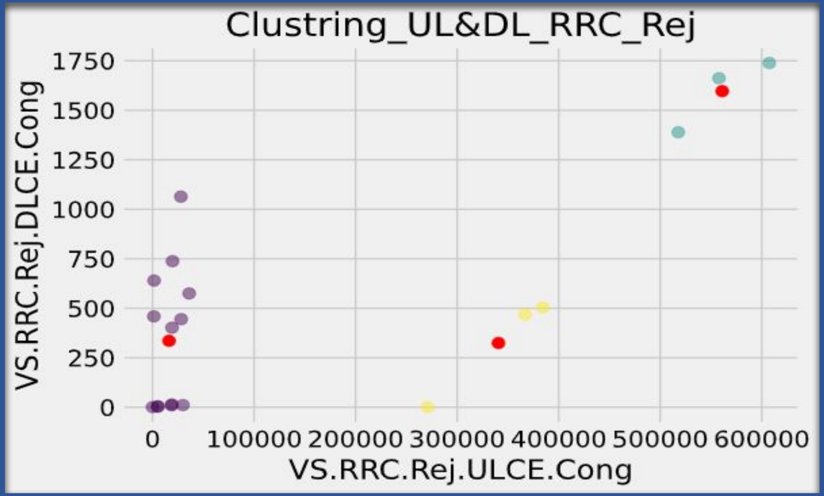


RRC_Attempt_Congestion_Ratio	VS.RRC.Rej.DLCE.Cong	num_cluster
87.76399106	1739	2
82.44618441	1662	2
78.92917002	469	2
68.75543346	504	2
64.73349016	1389	2
51.55631509	3	2
25.85079451	420	3
20.99417417	7	3
16.33902397	640	3
15.14900233	459	3
13.73230636	1	3
12.14943527	426	3
11.2260707	575	3
9.455092952	1064	3
8.663464146	738	3
8.05732923	1357	3
8.006311835	445	3
7.195308315	1	3
6.899713319	5	3
6.298216456	3	3
6.082193816	1	3
6.072717646	10	3
5.874101084	11	3
5.814333155	402	3
5.402911363	14	3

- **Cluster 2 contains 6 cells which has very high Congestion and some of cells suffer from high RRC Blocking due to DL CE.**
- **Cluster 3 contains 19 cells which has very high Congestion and some of cells suffer from high RRC Blocking due to DL CE.**

RRC Blocking due to UL CE & DL CE

Clustering cells which have (RRC Blocking due to UL & DL CE) and have high congestion (in cluster2 & cluster3) in pervious to get which has the highest blocking in both (DL & UL).



ENodeB	Cell Name	RRC_Attempt_Congestion_Ratio	VS.RRC.Rej.DLCE.Cong	VS.RRC.Rej.ULCE.Cong
[illegible]	[illegible]	87.76399106	1739	607451
ENodeB X	[illegible]	82.44618441	1662	557911
[illegible]	[illegible]	64.73349016	1389	517779
[illegible]	[illegible]	68.75543346	504	384314
[illegible]	[illegible]	78.92917002	469	366913
[illegible]	[illegible]	13.73230636	1	270955
[illegible]	[illegible]	11.2260707	575	36098
[illegible]	[illegible]	5.874101084	11	29916
[illegible]	[illegible]	8.006311835	445	28171
[illegible]	[illegible]	9.455092952	1064	27910
[illegible]	[illegible]	8.663464146	738	19719
[illegible]	[illegible]	5.814333155	402	19183
[illegible]	[illegible]	5.402911363	14	18956
[illegible]	[illegible]	6.072717646	10	18799
[illegible]	[illegible]	6.899713319	5	5338
[illegible]	[illegible]	6.298216456	3	5075
[illegible]	[illegible]	16.33902397	640	1501
[illegible]	[illegible]	15.14900233	459	1294
[illegible]	[illegible]	7.195308315	1	1

Cluster num	1	2	3
centers(x,y)	(16304.69,335.92)	(561047,1596.67)	(340727.3, 324.67)
Num of cells	13	3	3

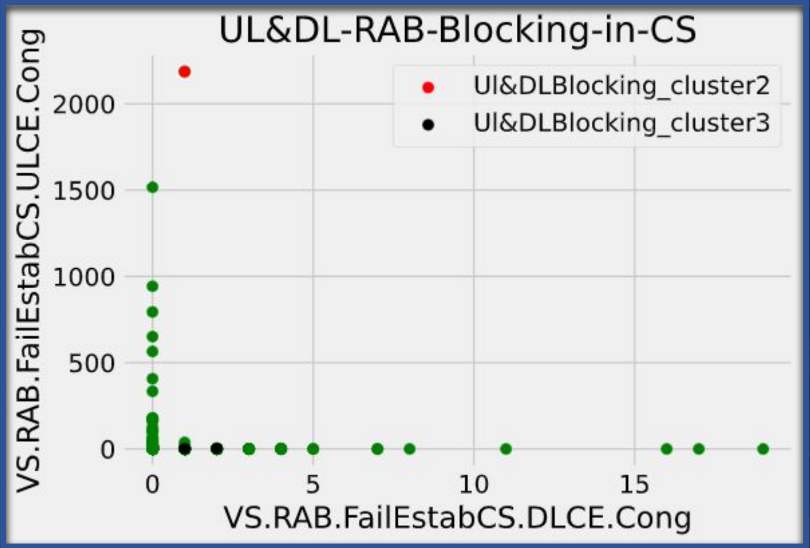
- Cluster2 has the highest RRC-Blocking due to Congestion caused by UL-CE and DL-CE .
- Cluster3 has high RRC-Blocking due to Congestion caused by UL-CE and DL-CE, but not like cluster2.
- Cluster1 has high RRC-Blocking due to UL CE.
- The ENodeB X has the highest blocking which means that it is in a high congestion.

2.3- RAB Blocking in CS Due to UL & DL CE

The next step is to monitor the RAB Blocking in CS due to UL & DL CE and correlate them with high RRC congestion ratio which is in cluster 2 and cluster 3 which calculated pervious.

- ❖ It was obvious that Cell Y is the highest block due to congestion on UL CE .

➔ The cell is in The same ENodeB X which has the highest RRC congestion ratio due to UL & DL CE.



ENodeB	Cell Name	VS.RAB.FailEstabCS.DLCE.Cong	VS.RAB.FailEstabCS.ULCE.Cong	num_cluster
ENodeB X	Cell Y	1	2187	2
[illegible]	[illegible]	2	3	3
[illegible]	[illegible]	1	2	3

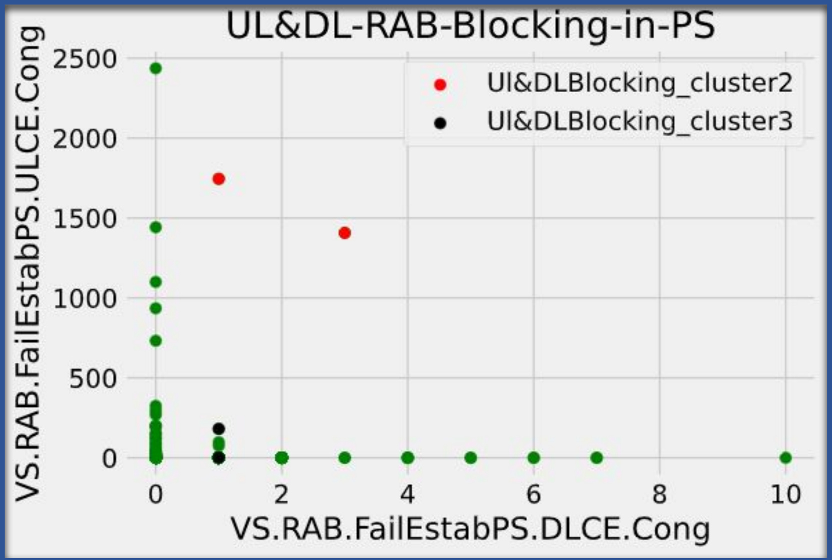
RAB Blocking in PS
Due to UL & DL CE

The next step is to monitor the RAB Blocking in PS due to UL & DL CE and correlate them with high RRC congestion ratio which is in cluster 2 and cluster 3 which calculated pervious.

❖ <u>It was obvious that :</u>

- Cell x has the highest block due to congestion on UL CE.
- Cell y also has a high block due to congestion on UL CE.

➔ The cells are in The same ENodeB X which has the highest RRC congestion ratio due to UL & DL CE.



ENodeB	Cell Name	VS.RAB.FailEstabPS.DLCE.Cong	VS.RAB.FailEstabPS.ULCE.Cong	num_cluster
ENodeB X	Cell y	3	1407	2
ENodeB X	Cell x	1	1745	2
[illegible]	[illegible]	1	181	3
[illegible]	[illegible]	1	2	3

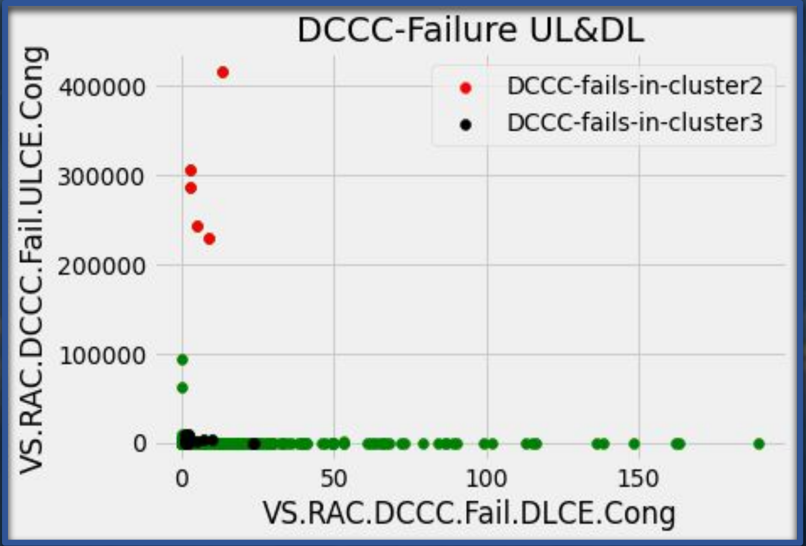
2.4- DCCC failures due to UL&DL CE Congestion

DCCC : Dynamic Channel Configuration Control.

DCCC is one of the most important RAN feature, that allocate dynamic resource according to the service request and it increase the radio resource utilization efficiency.

DCCC feature in Huawei 3G is mainly used to control the rate of best effort services on the DCH and E-DCH.

- Monitoring the DCCC failures due to UL&DL CE cong in the cells and correlate them with high RRC congestion ratio which is in cluster 2 and cluster 3 which calculated pervious.



Results:

➔ We found that there are 18 cells which having both high number of DCCC Failure due to UL & DL CE and high RRC Congestion Ratio.

ENodeB	Cell Name	VS.RAC.DCCC.Fail.DLCE.Cong	VS.RAC.DCCC.Fail.ULCE.Cong	num_cluster
[illegible]	[illegible]	3	286319	2
[illegible]	[illegible]	13	417281	2
[illegible]	[illegible]	9	228924	2
[illegible]	[illegible]	3	306820	2
[illegible]	[illegible]	5	244216	2
[illegible]	[illegible]	1	1	3
[illegible]	[illegible]	2	1	3
[illegible]	[illegible]	1	26	3
[illegible]	[illegible]	1	8824	3
[illegible]	[illegible]	2	4867	3
[illegible]	[illegible]	2	9230	3
[illegible]	[illegible]	24	235	3
[illegible]	[illegible]	23	255	3
[illegible]	[illegible]	5	1808	3
[illegible]	[illegible]	1	3081	3
[illegible]	[illegible]	7	4302	3
[illegible]	[illegible]	10	2823	3
[illegible]	[illegible]	1	4138	3

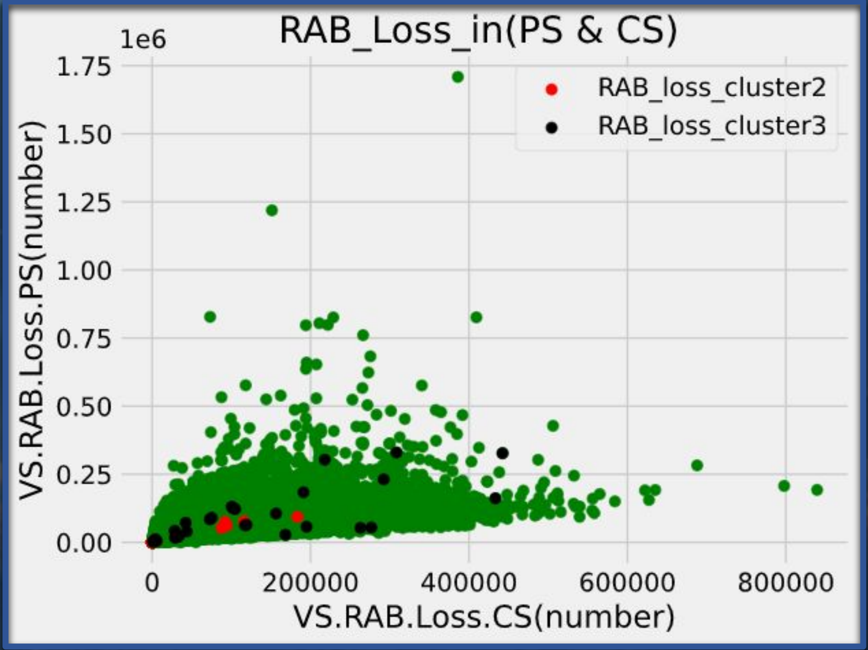
- Cluster 2 contains 5 cells which has very high RRC congestion ratio and very High number of DCCC failures due to UL & DL CE.
- Cluster 3 contains 13 cells which has medium RRC congestion ratio and High number of DCCC failures due to UL & DL CE.

2.5- RAB LOSS PS & CS

The next step was to monitor the RAB LOSS PS & CS in the cells and correlate them with high RRC congestion ratio which is in cluster 2 and cluster 3 which calculated pervious.

➔ We found that there are 44 cells which having both RAB LOSS PS & CS.

- 31 cells lie in cluster 3 which has medium congestion in RRC congestion ratio.
- 13 cells lie in cluster 2 which has very high congestion in RRC congestion ratio.



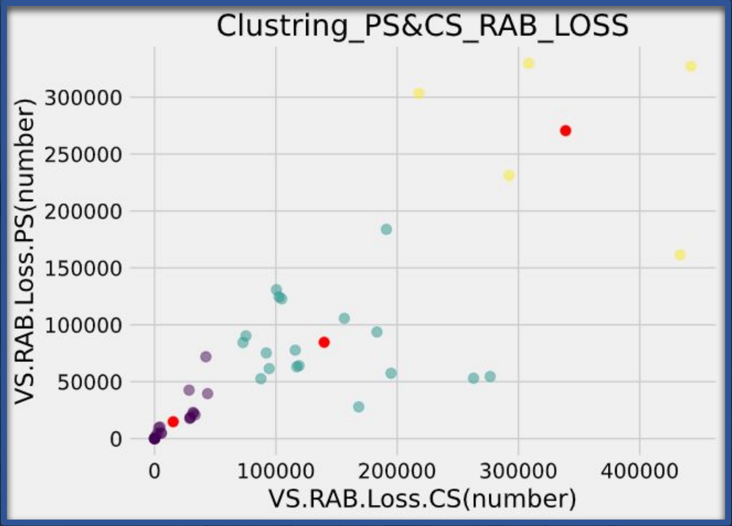
Results:

After that we will cluster RAB LOSS PS with RAB LOSS CS to differentiate between the LOSSES values, to get the cluster that has highly losses due to congestion.

- Cluster 1 has the least RAB losses in PS and CS, which lies in cluster 3 which has a medium congestion in the RRC_Congestion clustering.

- Cluster 2 has medium RAB losses in PS and CS, which 8 cells lie in cluster 2 which has the highest congestion in the RRC_Congestion clustering and 10 cells lie in cluster 3 which has a medium congestion in the RRC_Congestion clustering.

- Cluster 3 has the highest RAB losses in PS and CS, which lies in cluster 2 which has the highest congestion in the RRC_Congestion clustering.



Cluster num	1	2	3
centers(x, y)	(15332.48 , 14814.43)	(139815.556 , 84623.778)	(338900.8 , 270573.8)
Num of cells	21	18	5

2.6- Overload Congestion in RNC

In some cases, we find many cells in the same RNC suffer from the problems discussed before, so we check on the congestion of RNC to solve the main cause of these problems.

To detect the Overloaded RNC we calculated the following KPI:

$$\text{RNC Congestion ratio} = \frac{\textit{Number of cells where } \text{VS.LCC.OverCongNumUL} > 0 \text{ or } \textit{Number of cells where } \text{VS.LCC.OverCongNumDL} > 0}{\textit{Total Number of Cells in RNC}} * 100$$

Where:

VS.LCC.OverCongNumUL & VS.LCC.OverCongNumDL are Number of UL/DL Overload Congestions.

Overloaded RNC faces resource shortage for all the cells in this RNC, which affects access of new users and impacts the QoS of active users. Thus load imbalance seriously deteriorates the overall performance of the cellular network due to inefficient resource utilization.

RNC	OLC
[illegible]	77.45750185
[illegible]	52.47148289
[illegible]	85.84070796
[illegible]	72.92035398
[illegible]	57.04898447
[illegible]	59.5599393
[illegible]	92.51336898
[illegible]	81.39097744
[illegible]	95.76427256
[illegible]	96.65379665
[illegible]	91.53031761
[illegible]	96.53558052
[illegible]	91.61290323
[illegible]	85.57692308
[illegible]	68
[illegible]	91.96832579
[illegible]	93.53301566
[illegible]	89.91121872
[illegible]	62.69883351
[illegible]	92.80022766
[illegible]	89.46808511
[illegible]	90.86563994
[illegible]	89.29049531
[illegible]	67.68589298
[illegible]	58.51364064
[illegible]	57.47863248

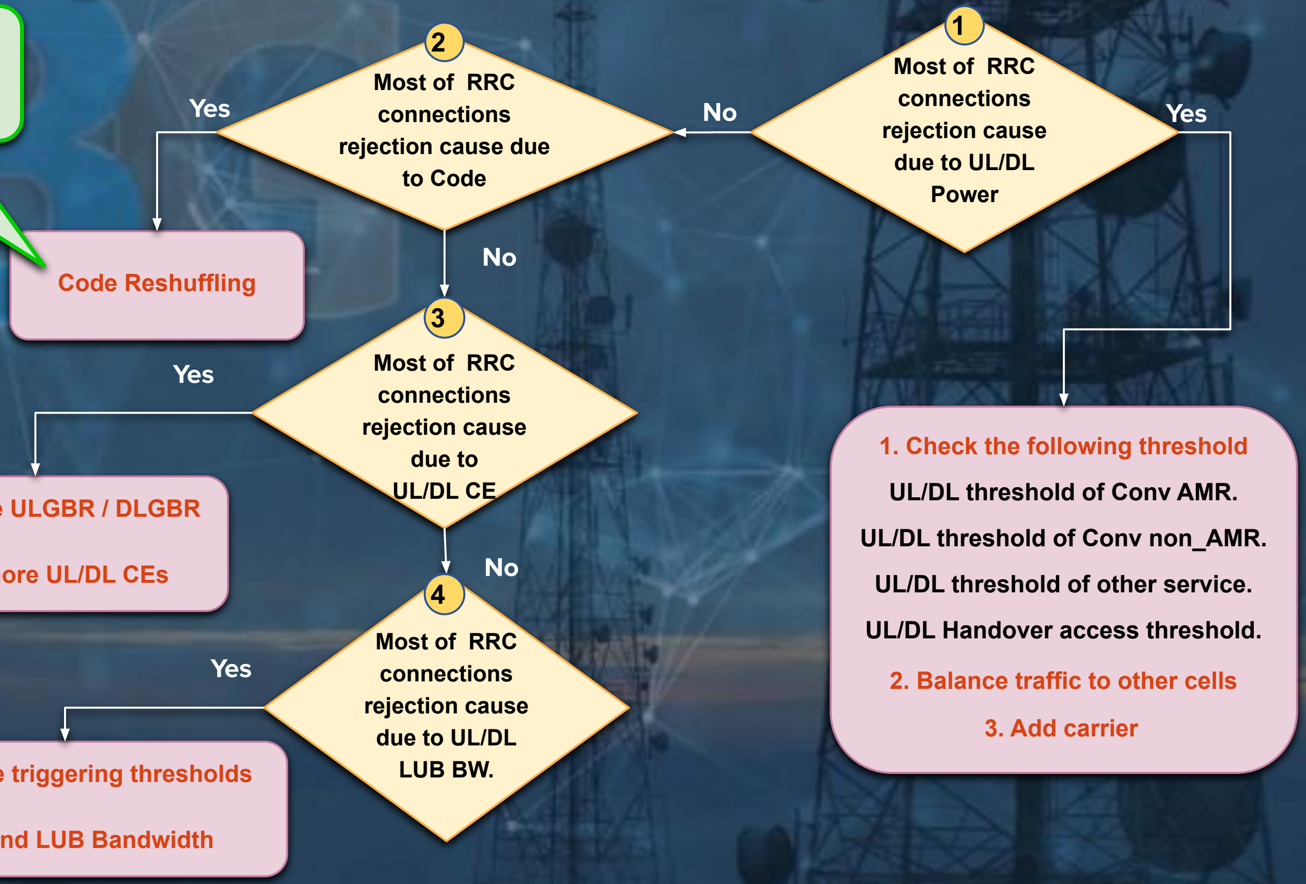
3- Solve 3G Capacity Problems

3.1- RRC Congestion Solution

3.2- Solve 3G Capacity Problems using specific Parameters

3.1- RRC Congestion Solution Algorithm

Purpose:
Sufficient code resources can be reserved for later service.



3.2- Adjust Specific Parameters To Improve Capacity of 3G Network

To solve the Capacity Problem in **3G CDMA network**, we recommend checking on specific parameters that may influence the capacity of the network and try to adjust their values to their default values.

Check The Parameters of:

- **Admission Control**
- **Cell Channel Power Distribution**

Admission Control Parameters

Resources Reserved for Common Channel Load
(ULCCHLOADFACTOR , DLCCHLOADRSRVCOEFF)

If
their values
are High

SO, This indicates that

Capacity is
LOW

- AMR Voice Uplink Threshold for Conversation Service (UlConvAMRThd)
- Non AMR Voice Uplink Threshold of Conversation Service (UlConvNonAMRThd)
- AMR Voice Downlink Threshold for Conversation Service (DlConvAMRThd)
- Non AMR Voice Downlink Threshold of Conversation Service (DlConvNonAMRThd)
- Uplink Threshold for Other Services (UlOtherThd)
- Downlink Threshold for Other Services (DlOtherThd)

If their
values are
too low

SO, This indicates that

The system resources may be wasted
Then,
The Target Capacity CANNOT be satisfied

Cell Channel Power Distribution Parameters

1

-- AICH Transmit Power (AICHPowerOffset)
-- PSCH and SSCH Transmit Power (PSCHPower , SSCHPower)
-- BCH Transmit Power (BCHPower)
-- Maximum FACH Transmit Power (MaxFachPower)
-- PCH Transmit Power (PCHPower)
-- PICH Transmit Power (PICHPowerOffset)

If **Too HIGH** SO → Other channels are interfered && the power resources are occupied. So, the cell capacity is influenced.

2

Cell PCPICH Transmit Power (PCPICHPower)

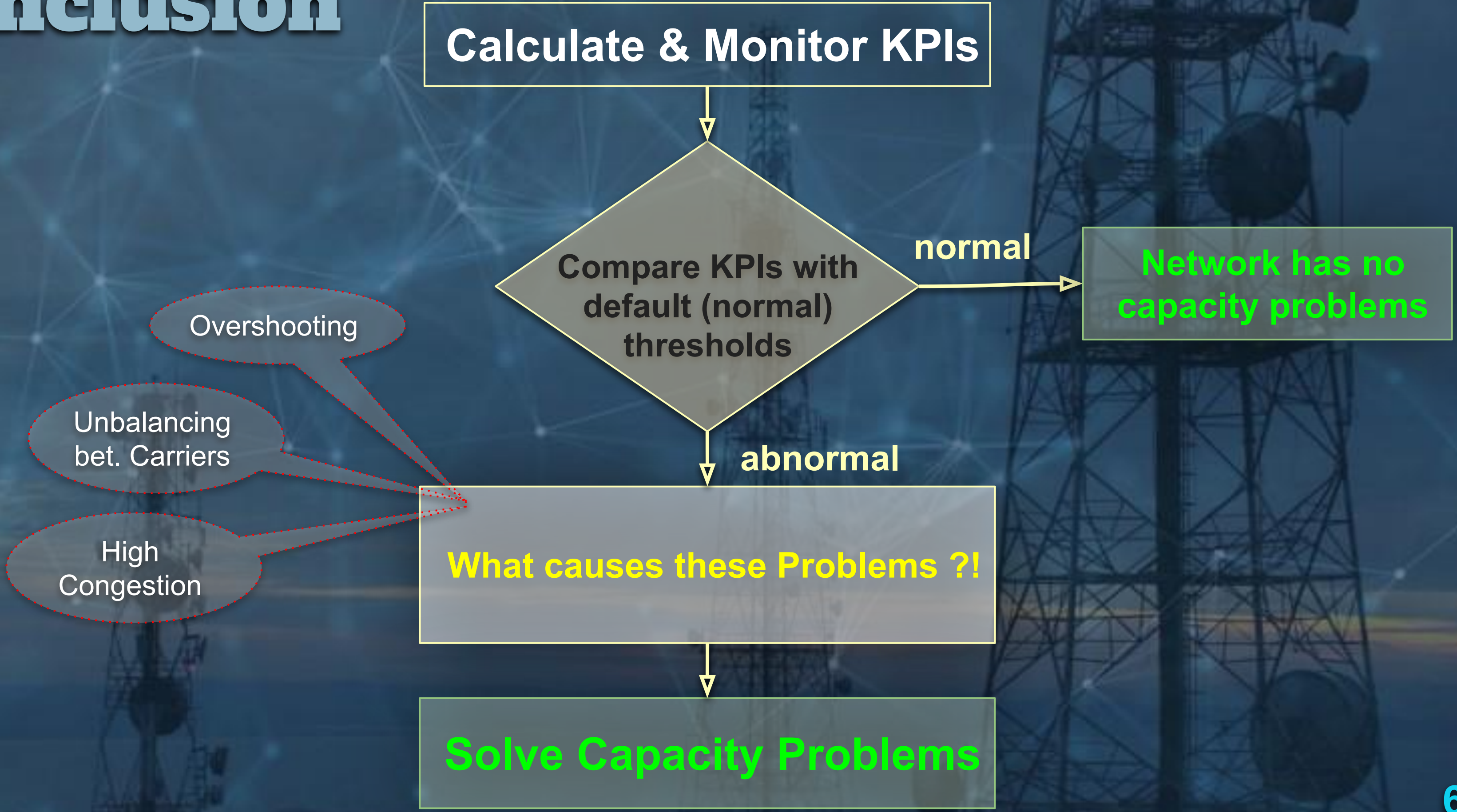
If **HIGH** SO → **DL interference Increases & Capacity Decreases**

3

Maximum Cell Transmit Power (MaxTxPower)

If **LOW** SO → **DL Capacity is Limited**

Conclusion


Calculate & Monitor KPIs
Compare KPIs with default (normal) thresholds
normal
Network has no capacity problems
abnormal
What causes these Problems ?!
Overshooting
Unbalancing bet. Carriers
High Congestion
Solve Capacity Problems


Thank You!