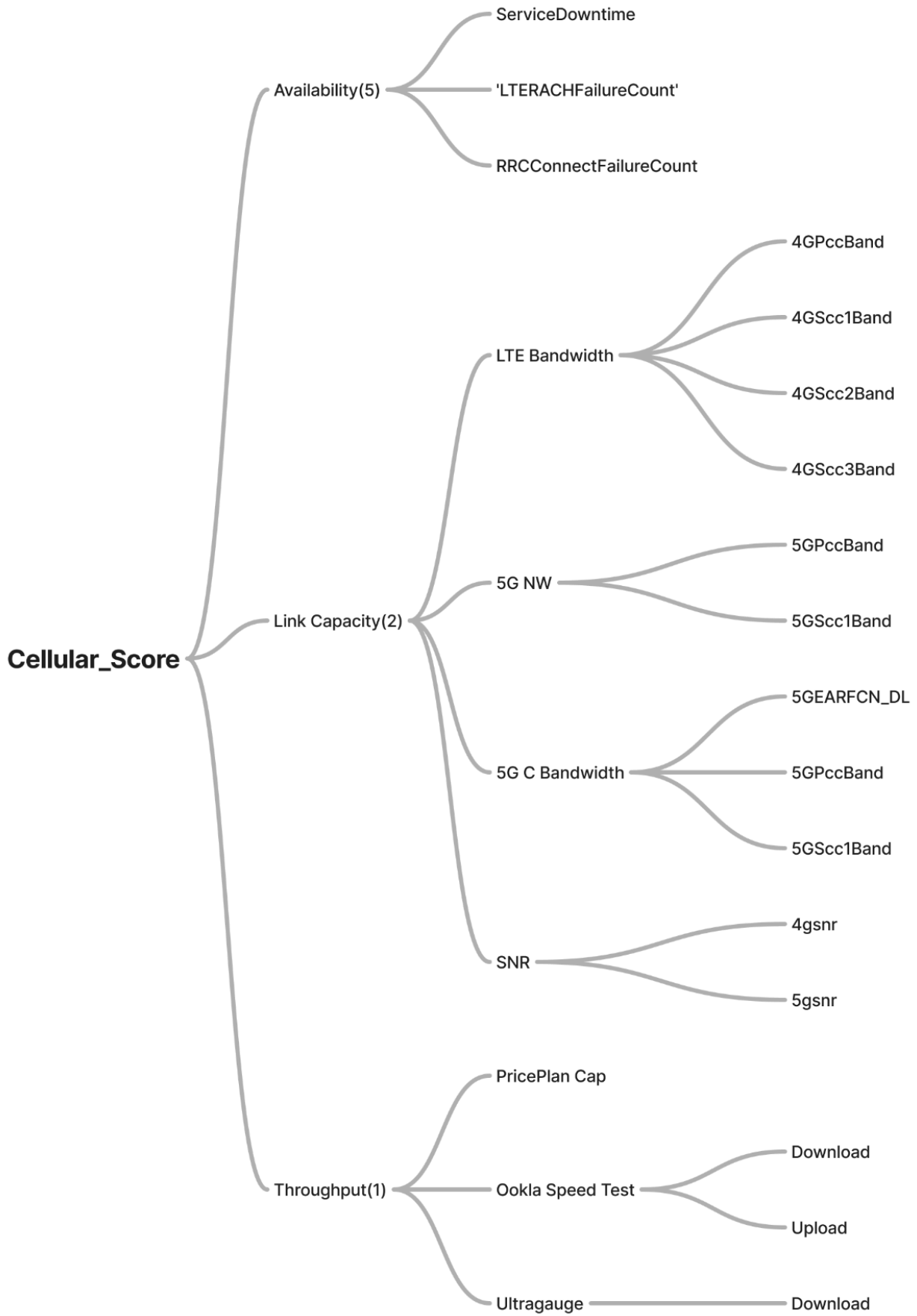


Overall Score per MDN for FWA Service

1. A daily score is computed per **Mobile Directory Number (MDN)**, which represents each FWA service account, to evaluate the cellular performance.
2. The daily score quantifies three main aspects—**Availability**, **Link Capacity/Quality**, and **Throughput**.
3. These individual scores are combined using **weights** to create a single, overall performance score for each MDN, making it easier to understand the service quality.

*the score shall only be computed for VCG devices that do not support mmWave: Titan 1/1.5, Titan 2, Titan 3, and Titan 4.



Availability Score Calculation

The system shall calculate the approximate percentage of time that Internet service was not available during the day.

- **Not Available Percentage:**
 - **Service Downtime:** Measures the time the service was offline.
 - **RACH (Random Access Channel) Failure Counts for LTE and NR:** Counts of connection attempts that failed for 4G (LTE) and 5G (NR) networks, assumed to incur a downtime of **0.01 seconds**
 - **Connection Failure Counts for LTE and NR:** Total counts of failed connections, assumed to incur a **downtime of 1 second**

Not Available Percentage = (Service Downtime + 0.01 * RACH Failure Counts + Connection Failure Counts)/Service time

$$\text{Not Available Percentage} = \frac{\text{Service Downtime} + 0.01 \times \text{RACH Failure Counts} + \text{Connection Failure Counts}}{\text{Service Time}}$$

- **Availability Score:**

$$\text{Availability Score} = 1 - (20 \times \text{Not Available Percentage}).$$

- The factor **20x** amplifies the impact of downtime on the score, as even brief outages significantly affect user experience.
 - A score of 0 is the minimum, even if the calculated value is negative. 1.2 hour downtime -> 0
-
- **Error check:**
 - These metrics are recorded as cumulative counts, so the system calculates the difference between the current and previous values to get the count for the day.
 - Error checks ensure values are accurate (e.g., cases where counts reset to zero or have abnormally high values).
 - If a downtime period spans two days (e.g., it starts late on day 1 and continues into day 2), the downtime is divided proportionately between the two days, and the score for day 1 might need updating to reflect this allocation.

Link Capacity/Quality Score Calculation

This score reflects the **bandwidth (download speed potential)** and **link quality (signal strength)** of the FWA service. Here's how it's calculated:

A. Bandwidth Estimation:

the system estimates the **downlink bandwidth per record** for **4G**, **5G nationwide**, and **5G C Band**, based on the device's reported network **band information**, (**4G Band**, **5G Band** and **5GEARFCN_DL** values.)

1. `_lte_band`

$$_lte_band = \begin{cases} 20 & \text{if } 4GPccBand > 0 \\ 0 & \text{otherwise} \end{cases} + \begin{cases} 20 & \text{if } 4GScc1Band > 0 \\ 0 & \text{otherwise} \end{cases} + \begin{cases} 20 & \text{if } 4GScc2Band > 0 \\ 0 & \text{otherwise} \end{cases} + \begin{cases} 20 & \text{if } 4GScc3Band > 0 \\ 0 & \text{otherwise} \end{cases}$$

2. `_nwbandwidth`

$$_nwbandwidth = \begin{cases} 20 & \text{if } (5GPccBand > 0) \wedge (5GPccBand \neq 77) \\ 0 & \text{otherwise} \end{cases} + \begin{cases} 20 & \text{if } (5GScc1Band > 0) \wedge (5GScc1Band \neq 77) \\ 0 & \text{otherwise} \end{cases}$$

3. `_cbandbandwidths`

$$_cbandbandwidths = \begin{cases} 160 & \text{if } (5GPccBand = 77) \wedge (5GScc1Band = 77) \\ 100 & \text{if } (5GPccBand = 77) \wedge (646667 \leq 5GEARFCN_DL \leq 653329) \\ 60 & \text{if } (5GPccBand = 77) \wedge (5GEARFCN_DL \notin [646667, 653329]) \\ 80 & \text{if } (5GPccBand \neq 77) \wedge (5GScc1Band = 77) \\ 0 & \text{otherwise} \end{cases}$$

```
+-----+-----+-----+-----+-----+-----+-----+-----+
-----+-----+-----+-----+-----+-----+-----+-----+
-----+
|          sn|          ts|
ModelName|_4gsnr|_5gsnr|4GPccBand|4GScc1Band|4GScc2Band|4GScc3Band|_lte_band|5G
PccBand|5GScc1Band|_nwbandwidth|5GEARFCN_DL|_cbandbandwidths|
+-----+-----+-----+-----+-----+-----+-----+-----+
-----+-----+-----+-----+-----+-----+-----+-----+
-----+
|AAM20705144|1736119136760| ASK-NCQ1338|    9.0|   29.0|          5|          66|
66|          0|          60|          77|          0|          0|        648672|
100|
|ABB30107226|1736117842378|ASK-NCQ1338FA|    4.8|   13.0|          66|          2|
66|          0|          60|          77|          0|          0|        653952|
60|
|AAM21003927|1736104744034| ASK-NCQ1338|   13.0|   26.0|          66|          2|
0|          0|          40|          77|          0|          0|        653952|
60|
|AAM20706210|1736087484618| ASK-NCQ1338|    9.0|   18.0|          2|          13|
66|          0|          60|          77|          0|          0|        648672|
100|
```

- B. **Quality Percentage:** Calculated by comparing **signal quality (SINR values)** to the **best possible values for 4G and 5G networks**.

1. **4G Quality%:**

$$4G \text{ Quality}\% = \min \left(1, \frac{4G \text{ SINR} + 11}{41} \right)$$

2. **5G NW Quality%:**

$$5G \text{ NW Quality}\% = \min \left(1, \frac{5G \text{ SINR} + 11}{41} \right)$$

3. **5G C Band Quality%:**

$$5G \text{ C Band Quality}\% = \text{C Band Bandwidths} \cdot 0.8 \cdot \min \left(1, \frac{5G \text{ SINR} + 10}{41} \right)$$

C. **Capacity** per Record

$$(4G \text{ Quality \%} \times 4G \text{ Bandwidth}) + (5G \text{ Nationwide Quality \%} \times 5G \text{ Nationwide Bandwidth}) +$$

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Rate_plan_adjustment =

$$\min \left(\frac{\text{DL Cap}}{150 \text{ Mbps}}, 1.0 \right)$$

```
+-----+-----+-----+-----+-----+-----+-----+
+-----+-----+-----+-----+-----+
|          sn|          ts|
ModelName|_4gsnr|_5gsnr|_lte_band|_nwbandwidth|_cbandbandwidths|lte_capacity|nw_capaci
ty|c_band_capacity|_capacity|
+-----+-----+-----+-----+-----+-----+-----+
+-----+-----+-----+-----+-----+
|AAM20705144|1736119136760| ASK-NCQ1338|   9.0|  29.0|         60|         0|
100|         29.27|         0.0|         76.1|         0.48|
|ABB30107226|1736117842378|ASK-NCQ1338FA|   4.8|  13.0|         60|         0|
60|         23.12|         0.0|         26.93|         0.23|
|AAM21003927|1736104744034| ASK-NCQ1338|  13.0|  26.0|         40|         0|
60|         23.41|         0.0|         42.15|         0.3|
|AAM20706210|1736087484618| ASK-NCQ1338|   9.0|  18.0|         60|         0|
100|         29.27|         0.0|         54.63|         0.38|
|AAM20706210|1736105940381| ASK-NCQ1338|   6.0|  22.0|         60|         0|
100|         24.88|         0.0|         62.44|         0.4|
```

AAM14611698 1736108732960	ASK-NCQ1338	9.2	23.0	40	0
100	19.71	0.0	64.39	0.39	
AAM21215937 1736083920030	ASK-NCQ1338	12.4	24.0	60	0
60	34.24	0.0	39.8	0.34	

D. Average Capacity per MDN

*Error checks shall be included to exclude records with invalid SINR values (<-10, >40, =0) or 0 bandwidth.

Throughput Score Calculation:

1.Score components

The throughput score measures the actual data speeds experienced by users, as follows:

- Ookla Speed Test: Measures download and upload speeds. If results exceed the user's plan limit (rate plan cap), the score is capped at 100%. Only successful tests are included.

$$\text{Downlink Score} = \frac{\text{Average of Ookla Speedtest Downlink Results}}{\text{Downlink Rate Plan Cap}}$$

$$\text{Uplink Score} = \frac{\text{Average of Ookla Speedtest Uplink Results}}{\text{Uplink Rate Plan Cap}}$$

- Ultragaugue Data: Measures **maximum** download speed achieved in the day, calculated relative to the plan's cap and capped at 100%. If no data is available, this component is excluded.

2. Score Aggregate

The three throughput scores are combined with weighted factors:

- Download weight (DL) = 4














- Upload weight (UL) = 1
- Ultragauge (UG) = 28

This was derived as follows: Verizon allocates for C band 4x more bandwidth for DL vs. UL, UG results are available daily which is typically 7x more than Ookla speedtests.

MDN_5G	CPE_MODEL_NAME	PPLAN_CD	DL_CAP	UL_CAP	UE_OVERALL_DL_SPEED	ULTRAGAUGE_DL_SCORE	DOWNLOADRESULT	Download_Score	UPLOADRESULT	Upload_Score	throughput_score	
AAM12500031	311480672567673	3159262296	ASK-NCQ1338	38365	50	6	362	1.0	47.0	0.94	4.0	0.6667
AAM13200938	311480672570865	2532817383	ASK-NCQ1338	38365	50	6	321	1.0	54.0	1.0	6.0	1.0
AAM13201324	311480672589105	2562248562	ASK-NCQ1338	50010	50	6	38	1.0	50.0	1.0	3.0	0.5
AAM13304280	311480672579216	7252495444	ASK-NCQ1338	50127	300	20	81	0.54	309.0	1.0	25.0	1.0

3. Missing value:

1. If the Ultragauge Downlink Score is greater than 100%, set it to 100%.
2. If all values are zero or no values are found, exclude this component from the Throughput score.
3. If any component is missing, it and its weight are excluded from the score calculation.

Last Modified	Replication	Block Size	Name	
Jan 02 19:10	0	0 B	datadate=2025-01-01	
Dec 30 22:21	0	0 B	datadate=2024-12-29	
Dec 27 22:10	0	0 B	datadate=2024-12-26	
Dec 26 22:20	0	0 B	datadate=2024-12-25	
Dec 23 22:14	0	0 B	datadate=2024-12-22	
Dec 22 22:23	0	0 B	datadate=2024-12-21	
Dec 17 22:18	0	0 B	datadate=2024-12-16	
Dec 16 19:23	0	0 B	datadate=2024-12-15	
Dec 13 22:29	0	0 B	datadate=2024-12-12	
Dec 11 21:52	0	0 B	datadate=2024-12-10	
Dec 10 22:33	0	0 B	datadate=2024-12-09	
Dec 09 22:22	0	0 B	datadate=2024-12-08	
Dec 08 21:57	0	0 B	datadate=2024-12-07	

Final Combined Score Calculation

The final score for each MDN combines Availability, Link Capacity/Quality, and Throughput scores. Each component has a weight:

$$\text{Daily Overall Score} = \left(\text{Availability Score} \times \frac{\text{Availability Weight}}{\text{Sum of Weights}} \right) + \left(\text{Capacity/Quality Score} \times \frac{\text{Capacity/Quality Weight}}{\text{Sum of Weights}} \right) + \left(\text{Throughput Score} \times \frac{\text{Throughput Weight}}{\text{Sum of Weights}} \right)$$

- Availability weight = 5
- Capacity/Quality weight = 2
- Throughput weight = 1

The final score uses a weighted average. If any component is missing, its weight is also excluded from the calculation.

If there is no data for any component for an MDN, the score for that day is recorded as null.

Example 1: All Components Available

<ul style="list-style-type: none">- Availability Score = 80%- Capacity/Quality Score = 70%- Throughput Score = 90%	Using the weights: <ul style="list-style-type: none">- Availability Weight = 5- Capacity/Quality Weight = 2- Throughput Weight = 1
---	---

1. Calculate the Sum of Weights:

$$\text{Sum of Weights} = 5 + 2 + 1 = 8$$

2. Apply the Equation:

$$\text{Daily Overall Score} = \left(80 \times \frac{5}{8}\right) + \left(70 \times \frac{2}{8}\right) + \left(90 \times \frac{1}{8}\right)$$

$$\text{Daily Overall Score} = 50 + 17.5 + 11.25 = 78.75\%$$

Example 2: Missing Throughput Score

<ul style="list-style-type: none">- Availability Score = 80%- Capacity/Quality Score = 70%- Throughput Score = null	Using the weights: <ul style="list-style-type: none">- Availability Weight = 5- Capacity/Quality Weight = 2- Throughput Weight = 1
--	---

1. Calculate the Adjusted Sum of Weights:

$$\text{Adjusted Sum of Weights} = 5 + 2 = 7$$

2. Apply the Equation Without the Missing Component:

$$\text{Daily Overall Score} = \left(80 \times \frac{5}{7}\right) + \left(70 \times \frac{2}{7}\right)$$

$$\text{Daily Overall Score} \approx 57.14 + 20 = 77.14\%$$

Category:

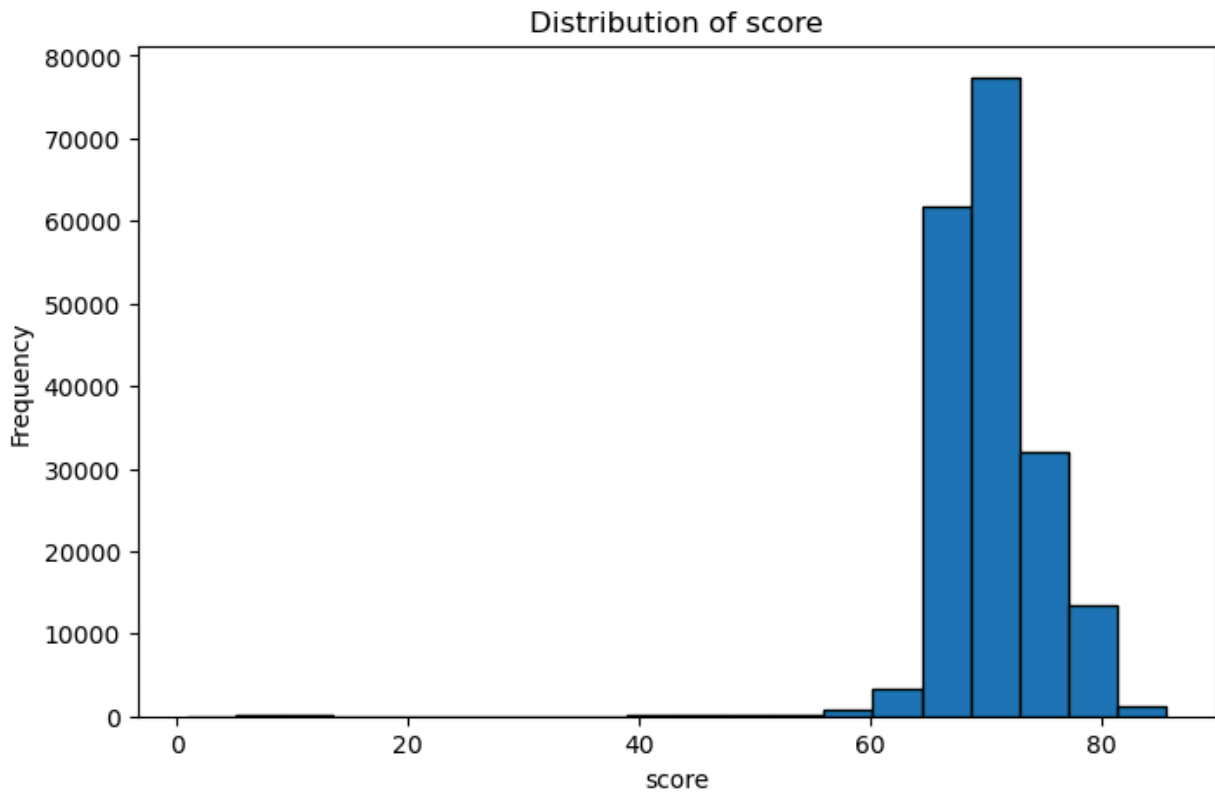
Python

```
.withColumn(
    "throughput_score_category",
    when(col("throughput_score").isNull(), None) # Set
NULL if throughput_score is NULL
    .when(col("throughput_score") >= 80, "Excellent")
    .when(col("throughput_score") >= 60, "Good")
    .when(col("throughput_score") >= 30, "Fair")
    .otherwise("Poor")
)

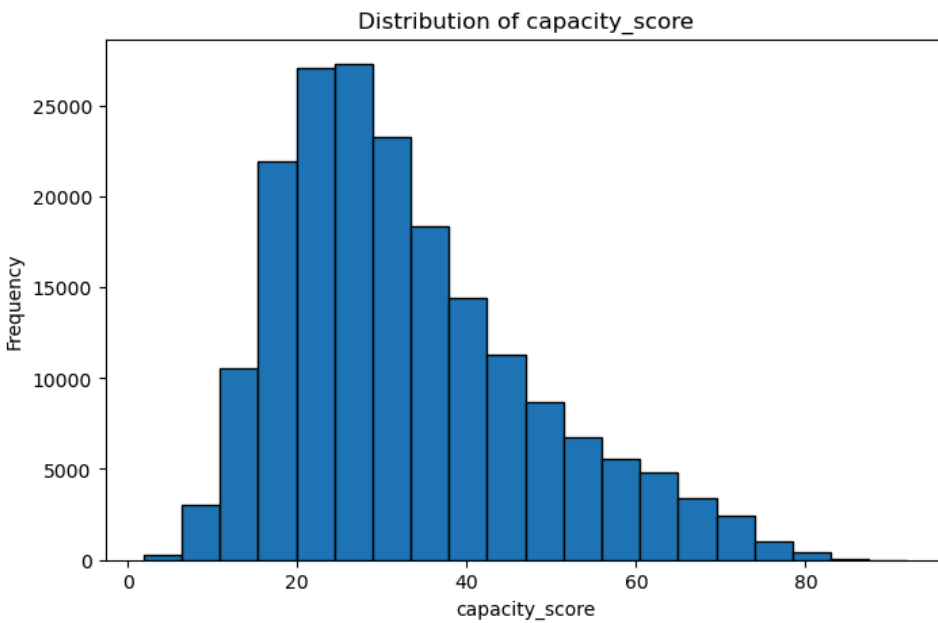
.withColumn( "availability_score_category",
    when(col("availability_score").isNull(),
None)
    .when(col("availability_score") == 100,
"Excellent")
    .when(col("availability_score") >= 99.77,
"Good")
    .when(col("availability_score") >= 97.22,
"Fair")
    .otherwise("Poor") )

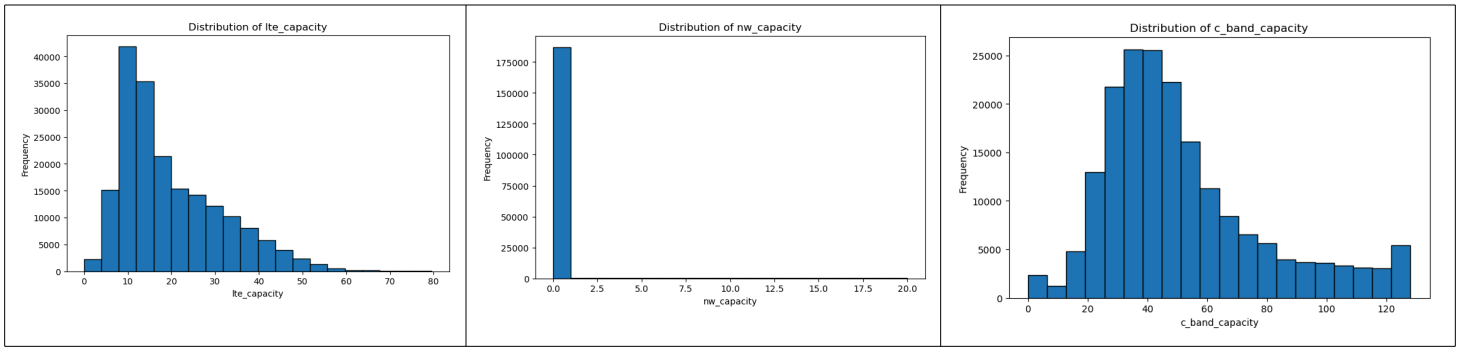
.withColumn( "capacity_score_category",
    when(col("capacity_score").isNull(), None)
    .when(col("capacity_score") >= 80, "Excellent")
    .when(col("capacity_score") >= 50, "Good")
    .when(col("capacity_score") >= 30, "Fair")
    .otherwise("Poor") )
```

Distribution



$$\frac{(4G \text{ Quality } \% \times 4G \text{ Bandwidth}) + (5G \text{ Nationwide Quality } \% \times 5G \text{ Nationwide Bandwidth}) + (5G \text{ Local Quality } \% \times 5G \text{ Local Bandwidth})}{218}$$





Balance of categorical design:

Lte_capacity score roughly ranges from 0 to 50, and it is difficult for stakeholders to interpret the meaning of the number, for example, people would naturally think 40 as 40 of 100, which is bad. However, since the majority of lte_capacity ranges from 5 to 50, 40 actually is a pretty good value.

Therefore, we suggest that convert the numerical value of lte_capacity to categorical value, such as excellent, good, fair and poor(maybe more categorical values). This could better help people understand the result.

On the other hand, this numerical->categorical transformation leads to a problem, neglecting the distinction. For example,

