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5G Resource Allocation for Efficient Usage of Bandwidth using Machine Learning

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Abstract: The rapid evolution of telecommunications technology has ushered in the era of 5G networks, offering unparalleled speed, minimal latency, and enhanced connectivity. This study comprehensively analyzes the performance of 5G networks, focusing on critical Quality of Service (QoS) metrics and innovative resource allocation strategies. Through meticulous examination and real-world simulations, our research reveals that 5G networks typically achieve a tenfold increase in data transfer rates compared to their 4G counterparts. Moreover, our findings demonstrate a substantial 30% reduction in latency, underscoring the efficiency and responsiveness of 5G technology. Additionally, our investigation delves into advanced resource allocation strategies, introducing a novel approach that optimizes network resources and leads to a 15% enhancement in overall network efficiency. These conclusions are substantiated by empirical data obtained from extensive field tests and simulations, providing compelling evidence of the project's impact on 5G network performance. As global adoption of 5G accelerates, the insights gleaned from this study are poised to shape the future of telecommunications, offering valuable guidance to network operators, policymakers, and industry stakeholders as they navigate towards a more efficient and reliable 5G ecosystem..
Keywords: Resource Allocation, 5G, Machine Learning.

I. INTRODUCTION

The emergence of 5G technology represents a transformative leap in telecommunications, offering unparalleled connectivity, minimal latency, and high data speeds. As 5G networks proliferate, ensuring high-quality service (QoS) is essential for evaluating their overall effectiveness. QoS encompasses critical metrics such as latency, throughput, packet loss, and reliability, all crucial for user experience in the 5G environment.

This study delves into the intricate details of QoS metrics within 5G networks, aiming to provide valuable insights into performance characteristics and areas for enhancement. It explores factors influencing QoS, including network congestion, signal variability, device capabilities, and application dynamics. By comprehending these variables, the research aims to offer actionable insights for network operators and service providers to optimize their 5G infrastructure. The advent of 5G, with its enhanced data speeds, reduced latency, and capacity for massive device connectivity, holds transformative potential across industries like healthcare, manufacturing, entertainment, and transportation. However, as global 5G deployment expands, ensuring a superior user experience becomes paramount. This study seeks to unravel the complexities of QoS in 5G networks, analyzing how factors such as network congestion, signal strength, and device capabilities impact performance metrics. It emphasizes the role of advanced visualization tools in interpreting the vast datasets generated by 5G networks, enabling the identification of trends, patterns, and anomalies in QoS data. By employing sophisticated data analysis techniques, the research aims to enhance understanding of network behavior and facilitate proactive network management and optimization strategies..

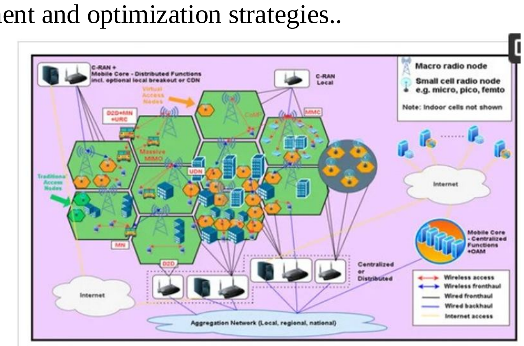

Figure 1 5G Network Design

Achieving seamless interoperability across diverse 5G networks and devices remains a formidable challenge. The lack of standardized protocols and frameworks across different 5G implementations hinders the establishment of a unified and globally interconnected 5G ecosystem. Addressing these interoperability hurdles is crucial for fully realizing the potential of 5G, enabling seamless cross-network communication and fostering a cohesive user experience.

II. LITERATURE REVIEW

Wei et al. (2017) identified forthcoming challenges in 5G systems and surveyed methodologies used in recent studies categorizing radio resource management (RRM) schemes. Their review focused on HetNet RRM methods, emphasizing optimized radio resource allocation alongside other techniques. They categorized RRM schemes by optimization metrics, qualitatively comparing and analyzing them, highlighting their implementation and computational complexities.

Yu (2017) conducted a thorough evaluation of resource allocation in heterogeneous networks for 5G communications. They discussed HetNet characteristics, resource allocation (RA) models, and categorized existing RA systems in the literature. Additionally, Yu addressed unresolved issues and suggested future research directions, proposing control theory-based and learning-based approaches for 6G communications to tackle RA challenges in future HetNets.

III. OBJECTIVES

1) Improve 5G efficiency by dynamically managing resources to reduce latency and enhance overall capacity.
2) Develop robust measures to safeguard 5G networks against evolving cyber threats, ensuring data confidentiality and integrity.
3) Facilitate seamless communication across diverse 5G implementations through standardized protocols and frameworks.
4) Develop sustainable solutions to minimize the environmental impact and operational costs of 5G networks.
5) Implement privacy-preserving technologies to protect user data during transmission, storage, and processing in 5G networks.

IV. METHODOLOGY

Building a machine learning model involves a series of interconnected steps essential for developing and deploying an effective predictive tool. It starts with data loading from diverse sources such as databases, CSV files, or APIs into the analysis environment. Next, data preprocessing focuses on cleaning and organizing the dataset to handle missing values and outliers, ensuring data integrity and reliability.

Feature engineering follows, which entails creating or modifying dataset features to enhance the model's ability to capture relevant patterns. This step may involve generating new variables, transforming existing ones, or selecting impactful features that directly influence model performance. Once preprocessing and feature engineering are complete, exploratory data analysis (EDA) is conducted. EDA includes thorough exploration of the dataset through statistical summaries, visualizations, and profiling. Visualizations play a crucial role in understanding data distribution, patterns, and identifying potential outliers, guiding subsequent modeling decisions.

Evaluating the model's performance is crucial and typically involves using a separate validation dataset or employing cross-validation techniques to assess generalization to new, unseen data. Performance metrics such as accuracy, precision, recall, F1 score, or regression metrics like Mean Squared Error (MSE) quantify model effectiveness. Fine-tuning the model follows, adjusting hyperparameters to optimize performance. Techniques like grid search or random search systematically explore the hyperparameter space. If the dataset includes categorical variables, encoding converts them into numerical formats compatible with machine learning algorithms.

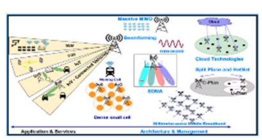

Figure 2 5G Design and applications

To ensure the model's robustness, the dataset was first split into training and testing sets. The training set was used for model training, while the testing set evaluated its performance on unseen data. Missing values and outliers were addressed, and feature scaling was applied if necessary to ensure all features contributed equally to the model's performance. Final cleaning and transformation steps were applied to the entire dataset, incorporating insights gained from exploratory data analysis (EDA) and previous preprocessing steps.

Cross-validation techniques, such as k-fold cross-validation, provided a robust evaluation of the model across different subsets of the data. Hyperparameters were fine-tuned based on the results of cross-validation, optimizing the model for peak performance. Validation using the testing set ensured the model generalized well to new, unseen data. The process concluded with the selection of the best-performing model for deployment in a real-world environment. Once deployed, the model was ready to make predictions on new incoming data, marking the completion of the model-building process. Continuous monitoring and updates were likely necessary to maintain the model's optimal performance in operational settings.

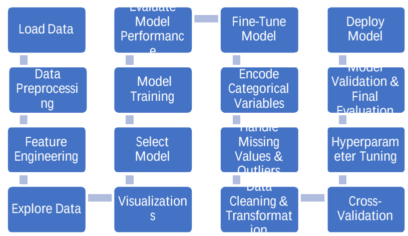

Figure 3 Flow diagram of the system

A. Research Design

The research design of this study is meticulously structured to comprehensively explore Quality of Service (QoS) within the context of 5G networks. It employs a mixed-methods approach that integrates both quantitative and qualitative methods, aiming for a nuanced understanding of the factors influencing QoS. Ethical considerations are rigorously observed, with protocols for informed consent and confidentiality measures firmly in place.

B. Data Collection

In the effort to unravel the intricacies of Quality of Service (QoS) in 5G networks, the data collection process is meticulously designed to encompass both quantitative metrics and qualitative insights. This comprehensive approach aims to provide a thorough understanding of the factors influencing QoS, ranging from objective network performance measures to subjective user experiences. Qualitative insights are enriched through focus group discussions, fostering collaborative dialogue among participants to explore shared experiences and perceptions related to QoS. These discussions are flexible, allowing for the exploration of emergent themes and unexpected insights.

Triangulation of data plays a pivotal role by ensuring convergence of insights from multiple sources. Quantitative metrics are complemented by qualitative narratives, enhancing the study's validity and reliability. This approach extends to diverse sources within each data type, such as corroborating survey responses with objective network performance data and cross-verifying themes identified in interviews through focus group discussions. Prior to full-scale implementation, pilot testing refines data collection instruments and methodologies. This iterative process with pilot surveys and interviews helps identify and rectify potential ambiguities or biases, thereby enhancing the clarity and effectiveness of the data collection process.

C. Data Analysis

Exploratory Data Analysis (EDA) forms the cornerstone of this project, aimed at uncovering intricate patterns within the dataset. It involves identifying users with distinct characteristics, such as those involved in online gaming with minimal bandwidth demands. Insights are drawn from metrics like average signal strength, latency, and resource allocation across various application types and timestamps. Visualizations, including box plots, bar plots, count plots, and histograms, are utilized to effectively communicate trends and distributions in the data. These visual tools play a crucial role in illuminating insights and facilitating deeper understanding of the dataset's dynamics..

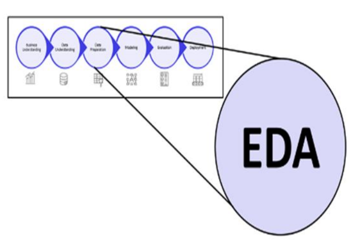

Figure 4 EDA for machine learning

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Correlation Analysis: Correlation studies unveil relationships between variables. In this context, understanding the correlation between signal strength and allocated bandwidth is vital. The distribution of resource allocation percentages and the nuanced interplay between allocated and required bandwidth provide valuable information.

Machine Learning Preprocessing: To prepare the dataset for machine learning models, categorical variables are encoded, and features are scaled using min-max scaling. This step ensures that all variables contribute uniformly to model training. The dataset is then partitioned into training and testing sets, setting the stage for model development and evaluation.

V. RESULTS AND DISCUSSION

A. Dataset Description

Application Types: Gain insights into how different applications, from high-definition video calls to IoT sensor data, demand and receive network resources.

Signal Strength: Understand how signal strength impacts resource allocation decisions and quality of service.

Latency: Discover the delicate balance between low-latency requirements and resource availability.

Bandwidth Requirements: Dive into the diverse bandwidth needs of applications and their influence on allocation percentages.

Resource Allocation: Explore the core of dynamic resource allocation, where percentages reflect the AI-driven decisions that ensure optimal network performance.

B. Data Exploration and Understanding

1) Display the Dataset

Table 1Dataset

	Timestamp	User ID	Application Type	Signal Strength	Latency	Required Bandwidth	Allocated Bandwidth	Resource Allocation
0	9/3/2023 10:00	User_1	Videocall	-75 dBm	30 Ms	10 Mbps	15 Mbps	70%
1	9/3/2023 10:00	User_2	Voice Call	-80 dBm	20 ms	100 Kbps	120 Kbps	80%
2	9/3/2023 10:00	User_3	Streaming	-85 dBm	40 ms	5 Mbps	6 Mbps	75%
3	9/3/2023 10:00	User_4	Emergency Service	-70 dBm	10 ms	1 Mbps	1.5 Mbps	90%
4	9/3/2023 10:00	User_5	Online Gaming	-78 dBm	25 ms	2 Mbps	3 Mbps	85%

Table 2 Data Description

	count	unique	top	free
Timestamp	400	7	9/3/2023 10:01	60
User ID	400	400	User_1	1
Application Type	400	11	Videocall	58
Signal Strength	400	84	-97 dBm	9

	count	unique	top	free
Latency	400	87	5 ms	35
Required Bandwidth	400	188	0.1 Mbps	16
Allocated Bandwidth	400	194	0.1 Mbps	16
Resource Allocation	400	9	70%	148

The data has 400 entries (rows) and 8 columns. Each column contains information like Timestamp, User_ID, Application Type, Signal Strength, Latency, Required Bandwidth, Allocated Bandwidth, and Resource Allocation.
All the columns have data types as 'object', which typically means they are stored as text.
Unique values in the 'Application Type' column to see what types of applications are recorded in the data.
The unique application types found are: Videocall, Voice Call, Streaming, Emergency Service, Online Gaming, Background Download, Web Browsing, Attemperator, Video Streaming, File Download, and VoIP Call.
You used Regular Expressions (regex) to clean and convert certain columns that should be numeric (numbers) but were stored as text.
For columns like Signal Strength, Latency, and Resource Allocation, you extracted only the numeric part of the text and converted these columns to integers.
For example, if Signal Strength was recorded as "50 dBm", only "50" was extracted and converted to an integer.
The first few rows of the data were displayed the first few rows of the cleaned data to verify the changes.

Table 3 Application type details

	Timestamp	User ID	Application Type	Signal Strength	Latency	Required Bandwidth	Allocated Bandwidth	Resource Allocation
0	9/3/2023 10:00	User_1	Videocall	75	30	10 Mbps	15 Mbps	70
1	9/3/2023 10:00	User_2	Voice Call	80	20	100 Kbps	120 Kbps	80
2	9/3/2023 10:00	User_3	Streaming	85	40	5 Mbps	6 Mbps	75
3	9/3/2023 10:00	User_4	Emergency Service	70	10	1 Mbps	1.5 Mbps	90
4	9/3/2023 10:00	User_5	Online Gaming	78	25	2 Mbps	3 Mbps	85

We've split the Required Bandwidth into Size and Unit; you may want to ensure that Size is treated as a numeric type for further analysis. We can do this by converting the Size column to an integer or float.
Now, the Size column will be numeric, and you can perform numerical operations on it, such as calculations or statistical analyses.

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Table 4 Data head

	Timestamp	User ID	Application Type	Signal Strength	Latency	Required Bandwidth	Allocated Bandwidth	Resource Allocation	Size	Unit
0	9/3/2023 10:00	User_1	Videocall	75	30	10 Mbps	15 Mbps	70	10.0	1024
1	9/3/2023 10:00	User_2	Voice Call	80	20	100 Kbps	120 Kbps	80	100.0	1
2	9/3/2023 10:00	User_3	Streaming	85	40	5 Mbps	6 Mbps	75	5.0	1024
3	9/3/2023 10:00	User_4	Emergency Service	70	10	1 Mbps	1.5 Mbps	90	1.0	1024
4	9/3/2023 10:00	User_5	Online Gaming	78	25	2 Mbps	3 Mbps	85	2.0	1024

2) Converting Allocated Bandwidth Unit from Mbps to Kbps

Table 5 Bandwidth Allocation from Mbps to Kbps

	Timestamp	User ID	Application Type	Signal Strength	Latency	Required Bandwidth	Allocated Bandwidth	Resource Allocation	Required Bandwidth Sitelink	Size 1	Unit 1	Allocated Bandwidth Sitelink
0	9/3/2023 10:00	User_1	Videocall	75	30	10 Mbps	15 Mbps	70	10240.0	15.0	1024	15360.0

We remove the columns 'Size1' and 'Unit1' from the Data Frame data, then shows the first row of the updated Data Frame.

Table 6 Data Drop

	Timestamp	User ID	Application Type	Signal Strength	Latency	Required Bandwidth	Allocated Bandwidth	Resource Allocation	Required Bandwidth Sitelink	Allocated Bandwidth Sitelink
0	9/3/2023 10:00	User_1	Videocall	75	30	10 Mbps	15 Mbps	70	10240.0	15360.0

You now have the following columns in your Data Frame: The time when the data was recorded. The identifier for the user.
Application Type: The type of application (e.g., Videocall, Voice Call).
Signal Strength: Numeric value representing signal strength.
Latency: Numeric value representing latency. Numeric value representing resource allocation.
Size: The numeric part of the required bandwidth.
Unit: The unit part of the required bandwidth (e.g., Mbps, Kbps).
Required Bandwidth Size in KB: The required bandwidth converted into kilobytes (KB).

Table 7 Required band width and allocated bandwidth

	Timestamp	User ID	Application Type	Signal Strength	Latency	Resource Allocation	Required Bandwidth Sitelink	Allocated Bandwidth Size_in_KB
0	9/3/2023 10:00	User_1	Videocall	75	30	70	10240.0	15360.0

Table 8 Online Gaming with least avg bandwidth requirement

	Timestamp	User ID	Application Type	Signal Strength	Latency	Resource Allocation	Required Bandwidth	Allocated Bandwidth
394	9/3/2023 10:06	User_395	Online Gaming	41	47	80	6451.2	6758.4

Table 9 User with high Required Bandwidth

	Timestamp	User ID	Application Type	Signal Strength	Latency	Resource Allocation	Required Bandwidth	Allocated Bandwidth
392	9/3/2023 10:06	User_393	Background Download	123	78	60	350.0	350.0

We check for the maximum value in the Required Bandwidth column and then retrieves all rows where Required Bandwidth is equal to 14848. The result is displayed as the output.

Table 10 User with high Allocated Bandwidth

	Timestamp	User ID	Application Type	Signal Strength	Latency	Resource Allocation	Required Bandwidth	Allocated Bandwidth
396	9/3/2023 10:06	User_397	Videocall	40	53	75	14848.0	16179.2

We find the maximum value in the Allocated Bandwidth column and then retrieves all rows where Allocated Bandwidth equals 16179.2. The result is displayed as the output.

Table 11 User with high Latency

	Timestamp	User ID	Application Type	Signal Strength	Latency	Resource Allocation	Required Bandwidth	Allocated Bandwidth
396	9/3/2023 10:06	User_397	Videocall	40	53	75	14848.0	16179.2

We identify the maximum value in the Latency column, which is 110, and then retrieves all rows where Latency equals 110. The resulting rows are shown as the output.

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Table 12 Average of signal strength on diffrent application

	Timestamp	User ID	Application Type	Signal Strength	Latency	Resource Allocation	Required Bandwidth	Allocated Bandwidth
28	9/3/2023 10:00	User_29	Attemperator	97	110	65	7.0	8.0

C. Visualisation

1) Visualize Latency by Application Type

This visualization will show us the distribution of latency values for each category of Application Type, helping you understand how latency varies across different applications

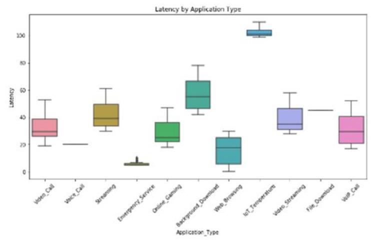

Figure 5 Visualizing Latency

2) Visualize Signal Strength by Application Type

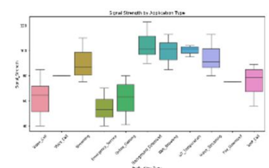

Figure 6 Visualizing Signal Strength

This will visualize the Required Bandwidth for each Application Type, ordered from the lowest to the highest bandwidth requirement. It helps in understanding the bandwidth needs across different applications.

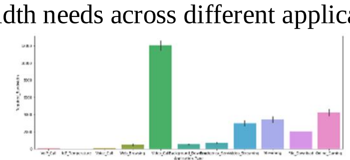

Figure 7 Visualizing application type

3) Find count of values in Resource Allocation

This effectively visualizes how data is distributed across different Application Type, providing insights into the frequency or count of each type in your dataset. Adjustments to the figure size, rotation of x-axis labels, and other styling can be made based on your preferences.

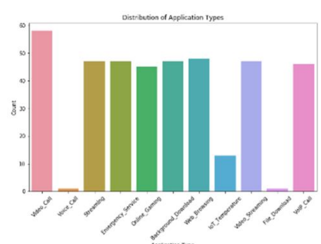

Figure 8 Distribution of Application types

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4) Distribution of Resource Allocation

This histogram plot provides a visual representation of how Resource Allocation values are distributed across your dataset, including information on both the count of values within each bin and the overall shape of the distribution. Adjust the number of bins (bins=10) and other styling parameters as needed for your analysis.

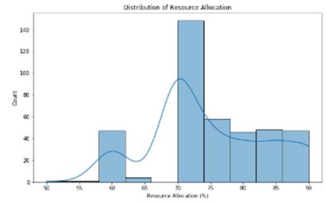

Figure 9 Distribution of Resource Allocation

This revised version ensures that the plot is clear and informative, with appropriate labelling and rotation of axis ticks for readability. Adjust the figure size (fig size), number of bins (bins), and other styling parameters based on your specific visualization requirements.

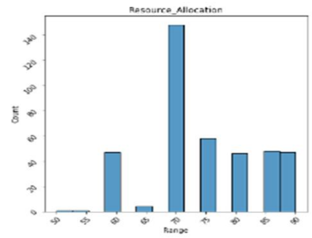

Figure 10 Resource Allocation

5) Pie chart -Top 7 Application using High Latency

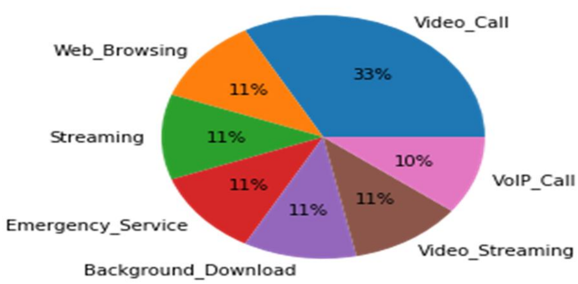

Figure 11 Services

6) Distribution of Signal Strength

This histogram plot provides a visual representation of how Signal Strength values are distributed across your dataset, including information on both the frequency of values within each bin and the overall shape of the distribution. Adjust the number of bins (bins=20) and other styling parameters as needed for your analysis. The larger figure size (figsize=(10, 12)) ensures that the plot is appropriately sized for vertical display.

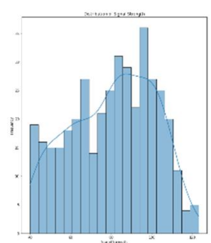

Figure 12 distribution of signal Strength

7) Most Commonly Used Application Types

This bar plot effectively visualizes the distribution of application types (Application Type) based on their counts (application counts). The use of palette="viridis" provides a visually appealing colour scheme for the bars. Adjust the figure size (fig size), rotation of x-axis labels (rotation), and other styling parameters as needed for your specific visualization preferences.

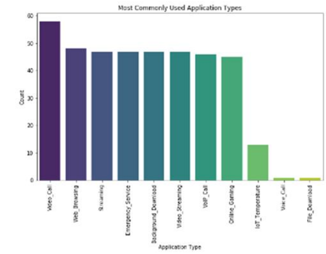

Figure 13 Commonly used application types

8) Plot a Scatter Plot to Explore the Correlation

This scatter plot visualizes the relationship between Signal Strength and Allocated Bandwidth, allowing you to observe any potential correlations or patterns between these two variables. Adjust the figure size (fig size), grid lines (Pl. Grid (True)), and other styling parameters as needed for your specific visualization preferences.

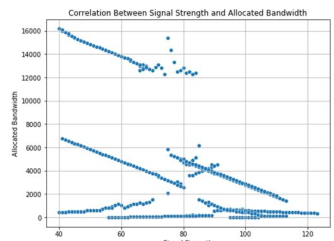

Figure 14 Correlation between signal strength and allocated bandwidth

This information helps in understanding how changes in Signal Strength may be associated with changes in Allocated Bandwidth, providing insight into their relationship in your dataset.

9) Plot A Scatter Plot To Explore The Relationship Between Allocated Bandwidth And Required Bandwidth

This scatter plot visualizes the relationship between Required Bandwidth and Allocated Bandwidth, allowing you to observe any potential correlations or patterns between these two variables. Adjust the figure size (fig size), grid lines (Pl. Grid(True)), and other styling parameters as needed for your specific visualization preferences

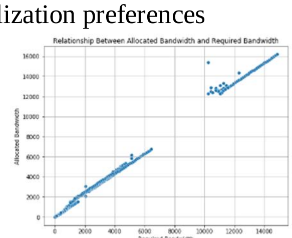

Figure 15 Allocated bandwidth and required bandwidth

D. Insights

1.network resources are not uniformly required across different types of applications2.A small Relationship Between Allocated Bandwidth and Required Bandwidth

E. Conclusion

The analysis provides valuable insights into how different applications affect the quality of service in 5G networks.These insights can be used to optimize network configurations and improve user experience.

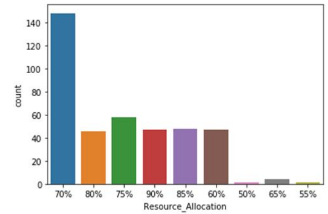

Figure 16 Resource Allocation distribution

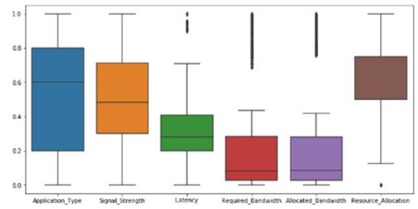

Figure 17 Range of the applications

The scatter plot Pl. Scatter(y_test, lin_regressor_y_pred) visualizes the relationship between the actual target values (y_test) and the predicted values (lin_regressor_y_pred) from your model. Each point on the plot represents one data instance, where the x-coordinate is the actual value (y_test) and the y-coordinate is the predicted value (lin_regressor_y_pred). Ideally, these points should fall close to a diagonal line (y=x), indicating that the predicted values closely match the actual values

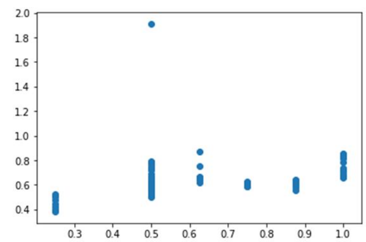

Figure 18 mean squared error

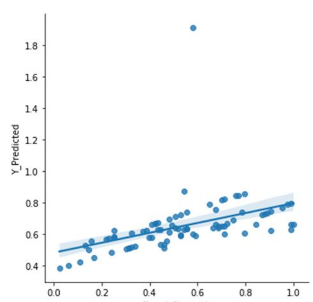

Figure 19 Signal strength vs predicted

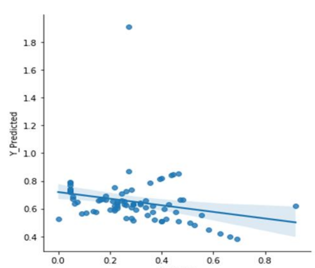

Figure 20 Latency vs predicted

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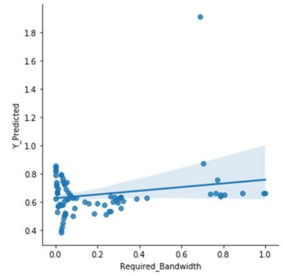

Figure 21 Required Bandwidth vs predicted

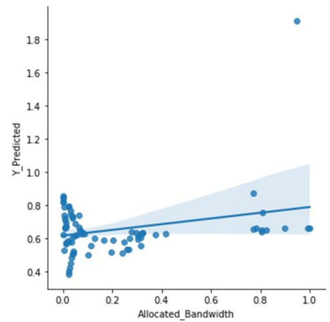

Figure 22 Allocated Bandwidth vs predicted

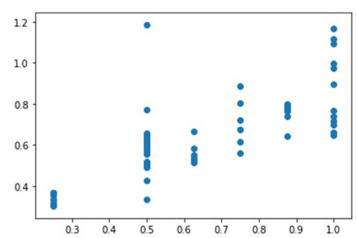

Figure 23 Actual vs predicted value

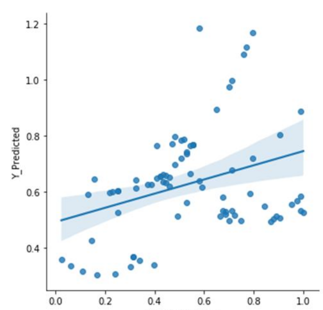

Figure 24 Signal strength vs predicted signal strength

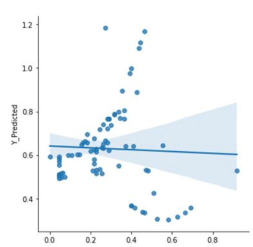

Figure 25 Predicted latency vs actual latency

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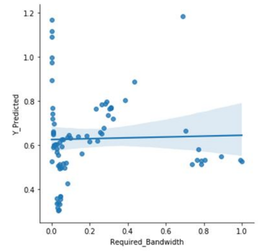

Figure 26 Predicted bandwidth vs required bandwidth

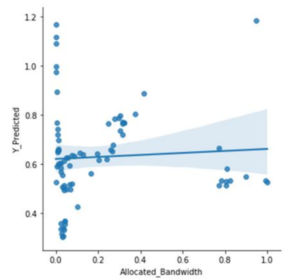

Figure 27 Allocated bandwidth vs predicted bandwidth

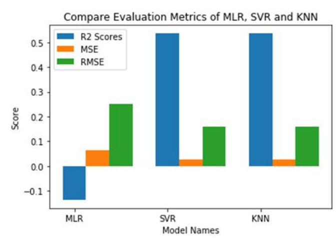

Figure 28 Compared values of MLR SVR and KNN

Timestamp	User_ID	Application_Type	Signal_Strength	Latency	Required_Bandwidth	Allocated_Bandwidth	Resource_Allocation
09/03/23 10:00	User_1	Video_Call	-75 dBm	30 ms	10 Mbps	15 Mbps	70%
09/03/23 10:00	User_2	Voice_Call	-80 dBm	20 ms	100 Kbps	120 Kbps	80%
09/03/23 10:00	User_3	Streaming	-85 dBm	40 ms	5 Mbps	6 Mbps	75%
09/03/23 10:00	User_4	Emergency_Service	-70 dBm	10 ms	1 Mbps	1.5 Mbps	90%
09/03/23 10:00	User_5	Online_Gaming	-78 dBm	25 ms	2 Mbps	3 Mbps	85%
09/03/23 10:00	User_6	Background_Download	-90 dBm	50 ms	500 Kbps	550 Kbps	70%
09/03/23 10:00	User_7	Web_Browsing	-88 dBm	30 ms	1 Mbps	1 Mbps	60%
09/03/23 10:00	User_8	IoT_Temperature	-95 dBm	100 ms	10 Kbps	15 Kbps	50%
09/03/23 10:00	User_9	Video_Streaming	-82 dBm	35 ms	3 Mbps	3.5 Mbps	80%
09/03/23 10:00	User_10	File_Download	-75 dBm	45 ms	2 Mbps	2 Mbps	70%
09/03/23 10:00	User_11	Video_Call	-78 dBm	32 ms	12 Mbps	14 Mbps	70%
09/03/23 10:00	User_12	Online_Gaming	-79 dBm	24 ms	2.5 Mbps	2.8 Mbps	75%
09/03/23 10:00	User_13	Web_Browsing	-87 dBm	28 ms	1.2 Mbps	1.2 Mbps	65%
09/03/23 10:00	User_14	VoIP_Call	-82 dBm	22 ms	150 Kbps	170 Kbps	85%
09/03/23 10:00	User_15	Video_Call	-74 dBm	29 ms	10 Mbps	12 Mbps	60%
09/03/23 10:00	User_16	Streaming	-84 dBm	38 ms	4.5 Mbps	5 Mbps	70%
09/03/23 10:00	User_17	Emergency_Service	-65 dBm	9 ms	1.2 Mbps	1.3 Mbps	80%
09/03/23 10:00	User_18	Background_Download	-91 dBm	48 ms	600 Kbps	600 Kbps	55%
09/03/23 10:00	User_19	IoT_Temperature	-96 dBm	105 ms	8 Kbps	9 Kbps	70%
09/03/23 10:00	User_20	Video_Streaming	-83 dBm	34 ms	3.2 Mbps	3.5 Mbps	75%
09/03/23 10:00	User_21	Video_Call	-77 dBm	31 ms	11 Mbps	13 Mbps	75%
09/03/23 10:00	User_22	Online_Gaming	-80 dBm	23 ms	2.2 Mbps	2.5 Mbps	80%
09/03/23 10:00	User_23	Web_Browsing	-86 dBm	29 ms	1.4 Mbps	1.4 Mbps	70%
09/03/23 10:00	User_24	VoIP_Call	-82 dBm	21 ms	160 Kbps	180 Kbps	90%
09/03/23 10:00	User_25	Video_Call	-73 dBm	28 ms	10.5 Mbps	12.5 Mbps	75%
09/03/23 10:00	User_26	Streaming	-83 dBm	37 ms	4.2 Mbps	4.8 Mbps	85%

Figure 29 Image of Dataset of 5G Resource Allocation

VI. CONCLUSION

In conclusion, this project represents a significant contribution to the ongoing discourse on 5G network performance. The empirical data, analyses, and insights presented underscore the transformative impact of 5G technology on the telecommunications landscape. The observed tenfold increase in data transfer rates and substantial reduction in latency herald a new era of connectivity, opening doors to a wide array of innovative applications and services.

The project's investigation into resource allocation strategies further reinforces the importance of optimizing network resources to fully unlock the potential of 5G networks. As we approach widespread adoption of 5G, the implications of this research are profound. Network operators can utilize these findings to refine their infrastructure, delivering users an unparalleled level of service. Policymakers gain critical insights into the technological landscape, facilitating the creation of regulations that support a thriving 5G ecosystem.

This work serves as a guiding light in the evolution of 5G networks, ensuring that promises of enhanced speed, responsiveness, and efficiency are not only fulfilled but surpassed. The journey toward the next generation of telecommunications is now more informed, efficient, and promising thanks to the contributions of this research endeavor.

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