Project Title :

AI-Driven Optimization of 5G Resource Allocation for Network Efficiency

Team ID : 592348

PROJECT REPORT

TEAM DETAILS

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CONTENTS

1. INTRODUCTION

1.1. Project Overview

The project, titled "AI-Driven Optimization of 5G Resource Allocation for Network Efficiency," harnesses the power of machine learning to transform the allocation of 5G network resources in India. In a country where 5G spectrum is divided into low, mid, and high bands, our advanced machine learning model factors in Application Type, Signal Strength, Latency, Required Bandwidth, and Allocated Bandwidth to intelligently predict resource allocation. With a robust technical architecture encompassing user authentication and authorization, and an intuitive user interface, this project simplifies 5G resource optimization. By doing so, it optimizes network performance, enhances user experience, and ushers in an era of seamless and responsive connectivity for diverse applications. This project is set to not only accelerate 5G technology in India but also make it smarter through the application of artificial intelligence.

1.2. Purpose

The primary purpose of this project, "AI-Driven Optimization of 5G Resource Allocation for Network Efficiency," is to revolutionize 5G network resource allocation in India. With the proliferation of 5G technology, it is crucial to efficiently distribute network resources for diverse applications. This project aims to accomplish that by leveraging machine learning. By considering key parameters such as Application Type, Signal Strength, Latency, Required Bandwidth, and Allocated Bandwidth, it provides data-driven resource allocation recommendations. This optimization leads to a network that can adapt to various user needs, ensuring faster speeds and low latency where required. It not only enhances the user experience but also boosts network efficiency and cost-effectiveness for service providers. In a rapidly evolving digital landscape, this project equips India with a sophisticated 5G infrastructure, making it a vital step toward a smarter and more connected future.

2. LITERATURE SURVEY

2.1. Existing problems

[1] In this paper, the minimum bandwidth resource allocation problem for non-orthogonal multiple access (NOMA) based machine to machine (M2M) communications in 5G and beyond cellular networks is investigated. In order to solve the problem fast and efficiently, a persistent resource allocation based polynomial-time algorithm considering NOMA and the periodicity of the machine type communication traffic is proposed. The algorithm consists of two phases. In first phase, M2M clusters are divided into NOMA sub-clusters using a technique that minimizes the number of NOMA sub-clusters for a set of devices. In second phase, NOMA sub-clusters are allocated to resource blocks (RB) considering their quality of service (QoS) requirements while achieving minimum bandwidth reservation. Through simulations, the performance of the proposed algorithm is presented in comparison to the previously proposed access grant time interval (AGTI) based radio resource allocation algorithms. It is illustrated that the proposed algorithm improves the spectrum-efficiency significantly.

[2] To achieve higher performance of allocation resources in the densely distributed scene of 5G networks, resources can be allocated considering the communication traffic of different areas. For this requirement, in this paper, a new allocation algorithm based on GCN-LSTM (Graph Convolution Network - Long Short-Term Memory) is proposed, which can provide an effective strategy for resource allocation. In this method, the historical 5G traffic data is divided into three time periods, and the spatial features of each period can be obtained through GCN. LSTM model is used to extract the temporal features. The combination of spatial and temporal features can achieve a high-precision prediction of 5G traffic data. Eventually, the 5G traffic prediction results of GCN-LSTM are used as the strategy basis for resource allocation. The simulation result demonstrates that the proposed algorithm can effectively improve the system throughput and spectral efficiency.

[3] When 5G slice network is applied to bear intelligent substation monitoring, one can obtain qualified service quality and reduce the slice rental cost, though reasonable and customized virtual network resources allocation among time-sensitive, mobile broadband, and narrow-band sensing services. As a result, the mapping model of electrical service demand onto communication and computing resources of network slices was established, and the mechanism and transformation between them are revealed. Constrained by the transmission bandwidth, time delay and computing resource demand of the electrical multiple services, the economic efficiency optimization problem of electric 5G multi-service network slice is formulated. A joint allocation algorithm of communication and computing resources is proposed to address the issue of efficient and economic resources utilization.

[4] The fast growth of machine-to-machine (M2M) communications in cellular networks brings the challenge of satisfying diverse Quality-of-Service (QoS) requirements of massive number of machine type communications (MTC) devices with limited radio resources. In this study, we first introduce the minimum bandwidth resource allocation problem for M2M communications in 5G and beyond cellular networks. NP-hardness of the problem is proven. Then, we propose a fast and efficient polynomial-time algorithm exploiting the periodicity of the MTC traffic based on persistent resource allocation. We prove a mathematical performance result for this algorithm considering a special case of the problem. Simulations show that the proposed algorithm outperforms the previously proposed clustering based radio resource algorithm significantly and performs very close to optimal.

[5] The significant improvement of 5G technology will be a huge driving force for the Internet of Things (IoT). Furthermore, the concept of network slice provides the possibility of customization for IoT applications. How to optimize resource allocation in multiple scenarios has become a challenge we are facing. In this paper, we propose a bandwidth resource's dynamic allocation scheme which is suitable for both Enhance Mobile Broadband (eMBB) scenario and Ultra Reliable and Low Latency Communication (uRLLC) scenario. Based on the classical Software Defined Network (SDN) architecture, admission control is introduced to maintain the resource utilization of the network, and the delay penalty factor we set can guarantee the low delay of the network. Besides, we make a trade-off between the benefit and the cost of network when adjusting resources. Simulation results show that the algorithm can meet the performance requirements of different application scenarios while minimizing the cost of dynamic resource adjustment.

[6] Users in vertical industries have a prominent demand for differentiated SLAs in the 5G era, especially the demand for large uplink and downlink bandwidth is increasing, With the explosive growth of 5G users, the gNodeB (gNB) pressure is gradually obvious, how to reasonably allocate wireless resources is an urgent problem. This paper creatively proposes a 5G quality of services (QoS) resource allocation optimization mechanism for gNB based on 5G to B (5G 2B) services, which can allocate wireless resource according to the differentiated needs for different users, also meet the needs of industry customers to the greatest extent. The mechanism and algorithm are simulated and verified in the current network environment of China Telecom Beijing, and the data results under different cases verify the feasibility of the proposed theory

[7] This paper proposed an online resource regulation strategy based on resource allocation benefit-state transition in 5G Fronthaul Network (5G-RAB ST). Results show that the presented system can significantly reduce the waste of resources in 5G fronthaul and highly improve the quality of users' service.

[8] This paper proposes novel insight that the performance of a network depends on the Resource Allocation Fairness level. In the observed network, 5G Ultra Dense Cellular Network with a single gateway, a macro cell consists of dozens of ENBs (Enode B) and a single gateway. When there is large variation in the traffic of each ENB in a macro cell there will be high performance loss. In order to maintain the network performance, a new formula to calculate an index which is called Harmony-in-Gradation Index is proposed. The index plays important role in determining the network performance. The main idea of resource allocation method with implementing the new formula is to maintain the ratio of an ENB traffic to its backhaul link capacity allocated by the gateway of each ENB in a macro cell to have a value that is in proximity to each other. This method is believed to be able to maintain a good network performance.

[9] User experience quality is an important performance indicator in the 5G era. By improving the quality of user experience, user satisfaction can be efficiently improved, thereby increasing user stickiness. Network resource allocation still plays a pivotal role in the development of 5G, and it also needs to adapt to the new needs of 5G development. This article first analyzes and studies the resource division and resource division mechanism of the 5G communication network. Then, in view of the current problem of co-channel interference, a MIMO-NOMA (Multiple Input Multiple Output-Non-Orthogonal Multiple Access) network resource allocation algorithm based on user clustering is proposed. Compared with the traditional network capacity, this algorithm guarantees the diverse service quality requirements of the network. The simulation results show that user clustering can effectively alleviate the simultaneous co-channel interference introduced by NOMA technology and improve the overall performance of the network. At the same time, the effective capacity also guarantees various QoS requirements such as speed, delay, and packet loss rate.

[10] 5G mobile network is predictable to assist flexible requirements henceforth dynamically allocate network resources according to the demands. Network slicing, where network resources are assigned and packaged in a customize manner to set of users according to their particular requirements, is measured as a key standard to fulfil diversity of requirements. There will obviously be conflicting demands in an allocation of such slices, and the effective provisioning of network slicing poses numerous challenges. Indeed, network slicing has a

twofold impact in terms of user/traffic prioritization as it dictates for the simultaneous management of the priority among different slices (i.e., inter-slice) and the priority among the users belonging to the same slice (i.e., intra-slice). In this paper, they proposed a novel resource allocation scheme able to dynamically allocate network resources to different slices in order to achieve the satisfaction of the users while guaranteeing to meet the requirements of the slices they belong to.

2.2. References

[1] https://ieeexplore.ieee.org/document/9477699/

[2] https://ieeexplore.ieee.org/document/9961174

[3] https://ieeexplore.ieee.org/document/9587151

[4] https://ieeexplore.ieee.org/document/8404840

[5] https://ieeexplore.ieee.org/document/9164338

[6] https://ieeexplore.ieee.org/document/9824982

[7] https://ieeexplore.ieee.org/document/9148065

[8] https://ieeexplore.ieee.org/document/8272913

[9] https://ieeexplore.ieee.org/document/9712674

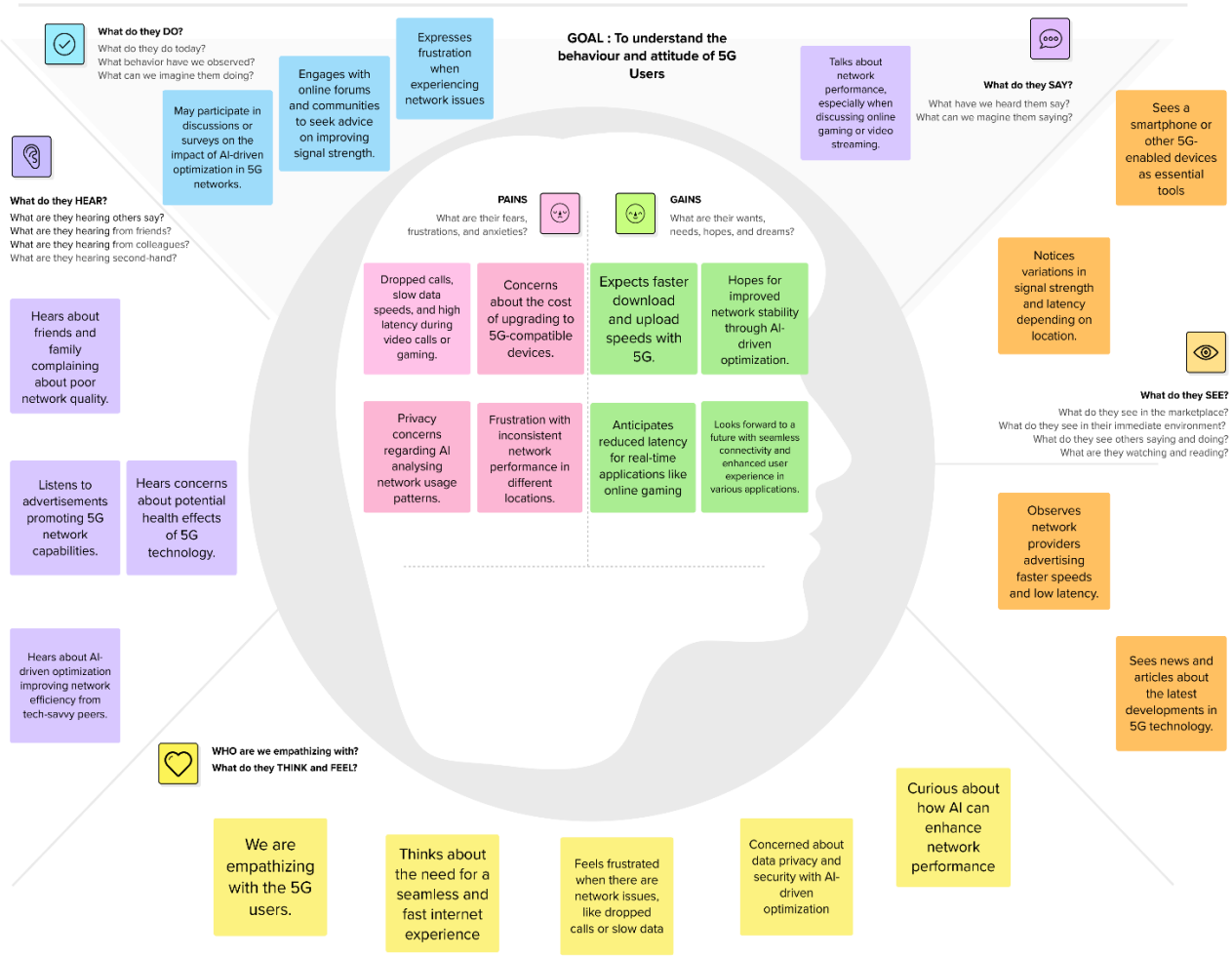
[10] https://ieeexplore.ieee.org/document/8418083

2.3. Problem Statement Definition

The project, "AI-Driven Optimization of 5G Resource Allocation for Network Efficiency," aims to address the critical challenge in 5G networks by optimizing the allocation of network resources. As 5G technology continues to revolutionize the telecommunications landscape, its diverse applications and dynamic user demands present a complex resource allocation problem. The problem statement revolves around the need to efficiently distribute resources, such as bandwidth and latency, across a network to ensure optimal performance, minimal latency, and reliable quality of service. Traditional allocation methods are often inadequate, especially in heterogeneous 5G environments. This project seeks to leverage artificial intelligence and machine learning to develop predictive models and adaptive algorithms that can intelligently allocate resources, thus enhancing network efficiency, reducing latency, and ensuring a seamless, high-quality user experience in the era of 5G.

3. IDEATION & PROPOSED SOLUTION

3.1. Empathy Map Canvas



The empathy map created above is designed to provide a concise yet comprehensive understanding of the 5G user's thoughts, feelings, observations, and actions in the context of AI-Driven Optimization of 5G Resource Allocation for Network Efficiency. This map encapsulates the user's mindset, environment, and behaviours by addressing six key aspects:

What does he think and feel?

This section delves into the user's thoughts and emotions, capturing their concerns, expectations, and curiosity about 5G technology and AI-driven network optimization.

What does he see?

It explores what the user observes in their environment, including the devices they use, network performance variations, and related news and advertisements.

What does he hear?

This aspect focuses on the information the user receives from various sources, such as friends, advertisements, and tech-savvy peers, which influences their perception of 5G and AI optimization.

What does he say and do?

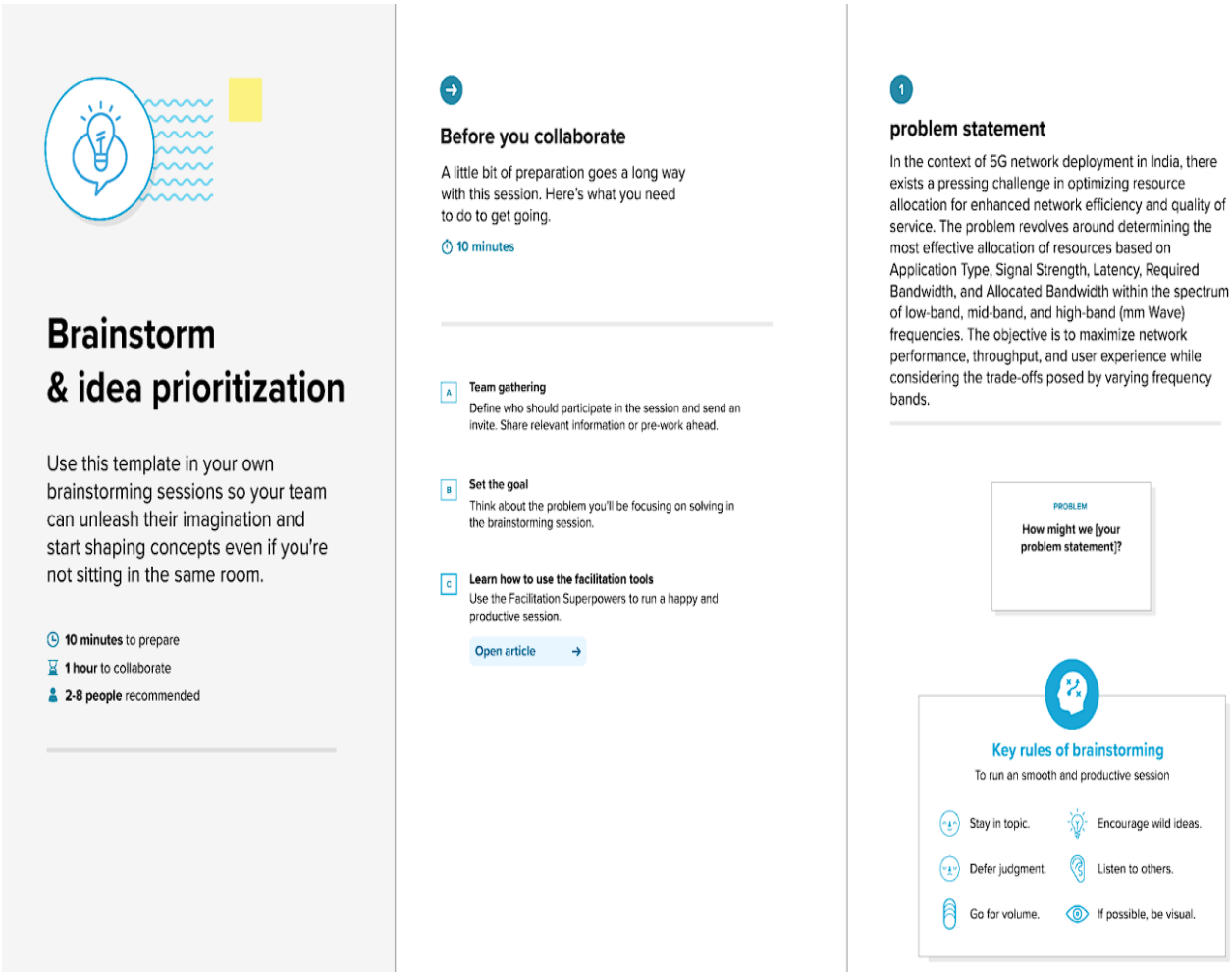
This section sheds light on the user's actions and behaviours, including their expressions of frustration, discussions about network performance, engagement in online forums, and participation in surveys.

Pain: It identifies the user's pain points, encompassing issues like network disruptions, privacy concerns, and frustration with inconsistent network quality.

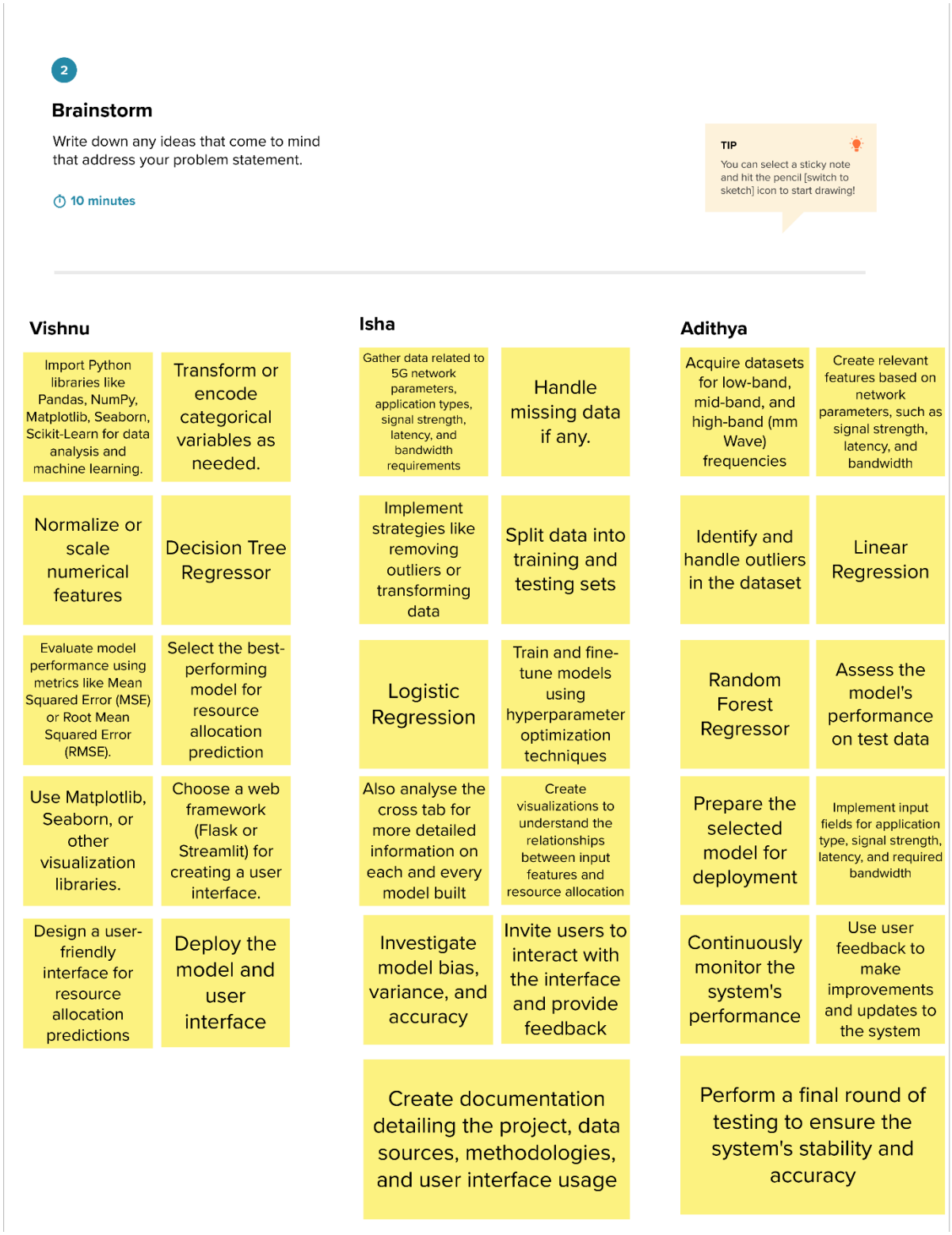
Gain: This part highlights the user's expectations and aspirations, such as anticipating faster speeds, reduced latency, and improved network stability through AI-driven optimization.

3.2. Ideation & Brainstorming

Step-1: Team Gathering, Collaboration and Select the Problem Statement



Step-2: Brainstorm, Idea Listing and Grouping



3

Group ideas

Take turns sharing your ideas while clustering similar or related notes as you go. Once all sticky notes have been grouped, give each cluster a sentence-like label. If a cluster is bigger than six sticky notes, try and see if you and break it up into smaller sub-groups.

20 minutes

TIP

Add customizable tags to sticky notes to make it easier to find, browse, organize, and categorize important ideas as themes within your mural.

Data Collection

- Gather data related to 5G network parameters, application types, signal strength, latency, and bandwidth requirements.
- Acquire datasets for low-band, mid-band, and high-band (mm Wave) frequencies.

Feature Engineering

- Create relevant features based on network parameters, such as signal strength, latency, and bandwidth.
- Transform or encode categorical variables as needed.
- Handle missing data if any, using techniques like imputation

Importing Necessary Libraries

- Import Python libraries like Pandas, NumPy, Matplotlib, Seaborn, Scikit-Learn for data analysis and machine learning.

Outlier Detection and Treatment

- Identify and handle outlieIdentify and handle outliers in the dataset. You can use techniques like the Z-score or IQR method for outlier detection.rs in the dataset.
- Implement strategies like removing outliers or transforming data.

Data Preprocessing

- Normalize or scale numerical features.
- Split data into training and testing sets.

Performance Testing

- Assess the model's performance on test data. Investigate model bias, variance, and accuracy.
- Analyze the model's predictions and compare them to the actual resource allocations.

Model Building

- Explore various machine learning regression algorithms as mentioned (Linear Regression, Decision Tree Regressor, Random Forest Regressor).
- Train and fine-tune models using hyperparameter optimization techniques (e.g., GridSearchCV or RandomizedSearchCV).

Best Model Selection

- Evaluate model performance using metrics like Mean Squared Error (MSE) or Root Mean Squared Error (RMSE).
- analyse the cross tab for more detailed information on each and every model built.
- Select the best-performing model for resource allocation prediction.

Data Visualization

- Create visualizations to understand the relationships between input features and resource allocation.
- Use Matplotlib, Seaborn, or other visualization libraries.

Model Deployment

- Prepare the selected model for deployment by saving the model and its necessary preprocessing steps (e.g., scalers, encoders).

Integration of Flask or streamlit

- Choose a web framework like Flask or Streamlit for creating a user interface.

Creating User Interface

- Design a user-friendly interface for resource allocation predictions. Implement input fields for application type, signal strength, latency, and required bandwidth in your chosen framework.

User Testing

- Invite users to interact with the interface and provide feedback.

Deployment and Monitoring

- Deploy the model and user interface to a web server or cloud platform.
- Continuously monitor the system's performance and resource utilization.

Feedback Iteration

- Use user feedback to make improvements and updates to the system, both in terms of the model and the user interface.

Documentation

- Create documentation detailing the project, data sources, methodologies, and user interface usage.

Final Testing

- Perform a final round of testing to ensure the system's stability and accuracy.

Step-3: Idea Prioritization

4

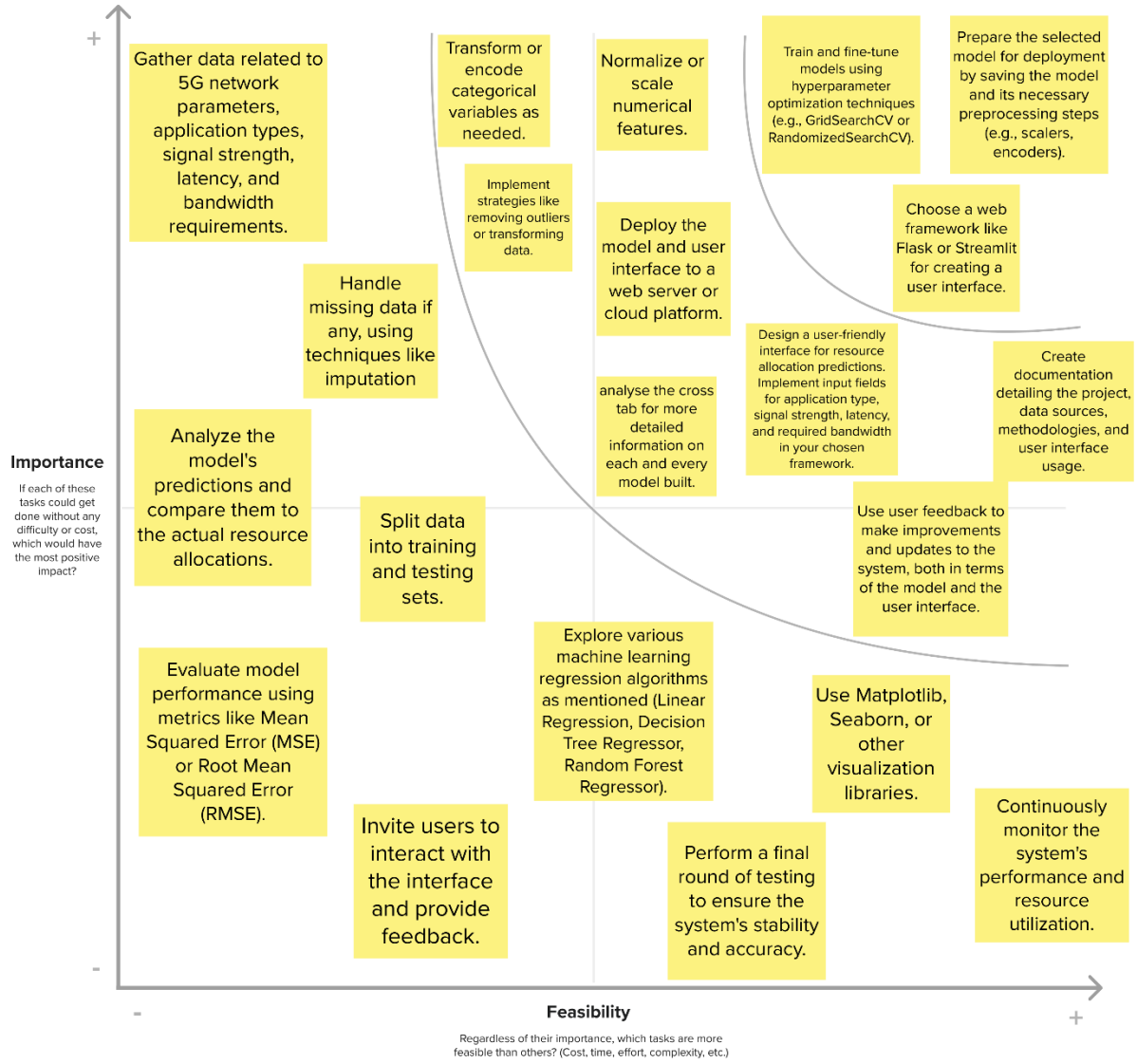
Prioritize

Your team should all be on the same page about what's important moving forward. Place your ideas on this grid to determine which ideas are important and which are feasible.

20 minutes

TIP

Participants can use their cursors to point at where sticky notes should go on the grid. The facilitator can confirm the spot by using the laser pointer holding the **H key** on the keyboard.



4. REQUIREMENT ANALYSIS

4.1. Functional requirement

1. **User Authentication and Authorization:** The system must provide user authentication and authorization mechanisms to ensure that only authorized users, including administrators and regular users, can access and interact with the application.
2. **Input Parameters:** Users should be able to enter specific parameters relevant to the 5G resource allocation, including Application Type, Signal Strength, Latency, Required Bandwidth, and Allocated Bandwidth.
3. **Machine Learning Model:** The system must integrate a machine learning model capable of predicting resource allocation based on the input parameters provided by users.
4. **Prediction:** After inputting the necessary parameters, the system should promptly return predictions regarding the optimal resource allocation, including bandwidth and latency, for network efficiency.
5. **User Interface:** The user interface should be user-friendly and provide a seamless experience for entering parameters, viewing predictions, and navigating the application.

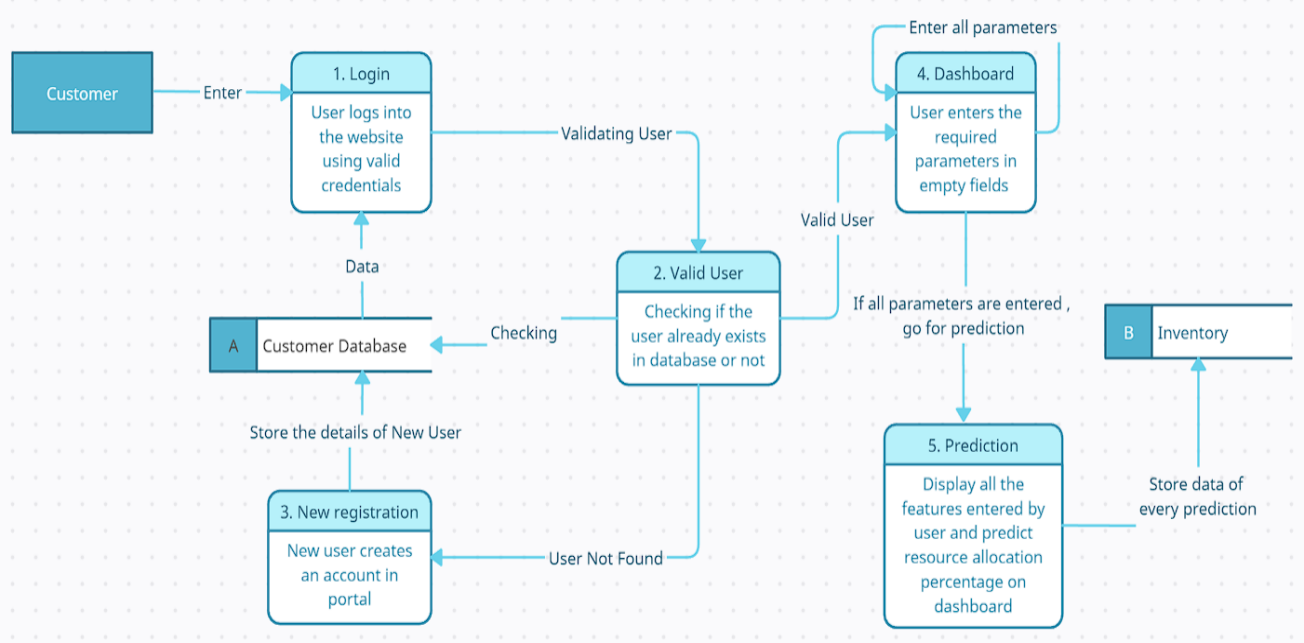
4.2. Non-Functional requirements

1. **Security:** The application must ensure data security, including encryption for user credentials, to protect sensitive information.
2. **Performance:** The machine learning model should provide predictions with low latency to support real-time or near-real-time resource allocation.
3. **Scalability:** The system should be designed to handle potential increases in user load as the application gains popularity.
4. **Usability:** The user interface should be intuitive and easy to use, requiring minimal training for users to interact with the system effectively.
5. **Reliability:** The system should have a minimal error rate in predicting resource allocations, ensuring high reliability for network optimization.
6. **Privacy:** User data privacy should be a priority, with compliance to data protection regulations.
7. **Compatibility:** The application should work on various devices and browsers to accommodate a broad user base.
8. **Maintainability:** The codebase and machine learning model should be well-documented and maintainable for future updates and improvements.
9. **Response Time:** The system should respond promptly to user interactions, offering quick predictions and efficient navigation within the application.

5. PROJECT DESIGN

5.1. Data Flow Diagrams & User Stories

Data Flow Diagram:



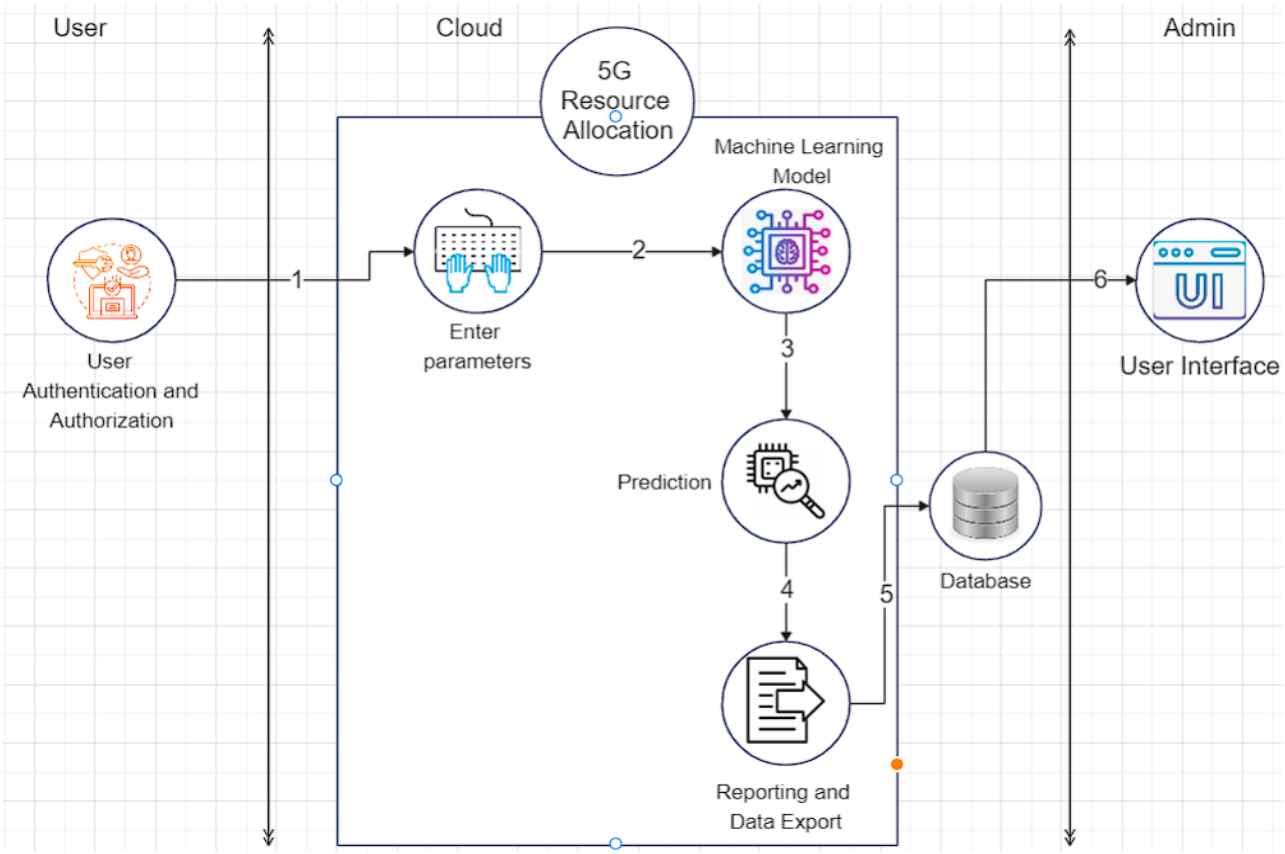
User Stories:

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
Mobile User	Registration	USN-1	As a mobile user, I want to register on the 5G optimization platform to access its features.	User can provide valid registration details.	High	Sprint-1
		USN-2	As a registered mobile user, I want to reset my password in case I forget it.	User can request a password reset.	Medium	Sprint-2
	Login	USN-3	As a mobile user, I want to log in to the 5G optimization platform with my credentials.	User can provide valid login credentials.	High	Sprint-1
		USN-4	As a logged-in mobile user, I want to log out of the platform securely.	User can log out, and their session is terminated.	Medium	Sprint-2
	Dashboard	USN-5	As a mobile user, I want to view a dashboard that displays network performance metrics.	User can access a dashboard with real-time performance data.	High	Sprint-1
		USN-6	As a mobile user, I want to customize my dashboard to display specific metrics.	User can select and arrange metrics on the dashboard.	Medium	Sprint-3
Web User	Registration	USN-7	As a web user, I want to create an account on the platform to access optimization features.	User can provide valid registration details.	High	Sprint-1
		USN-8	As a registered web user, I want to reset my password if I forget it.	User can request a password reset.	Medium	Sprint-2
	Login	USN-9	As a web user, I want to log in to the platform using my credentials.	User can provide valid login credentials.	High	Sprint-1
		USN-10	As a logged-in web user, I want to log out securely to end my session.	User can log out, and their session is terminated.	Medium	Sprint-2
	Dashboard	USN-11	As a web user, I want to access a dashboard displaying network performance data.	User can view the dashboard with real-time performance data.	High	Sprint-1

		USN-12	As a web user, I want to personalize my dashboard by selecting specific performance metrics.	User can choose and arrange metrics on the dashboard.	Medium	Sprint-3
Customer Care Executive	Dashboard	USN-13	As a customer care executive, I want access to a dashboard to monitor network performance.	User can access the dashboard with real-time performance data.	High	Sprint-1
		USN-14	As a customer care executive, I want the ability to view network performance metrics in real-time.	User can see updated performance metrics.	Medium	Sprint-2
	Reporting	USN-15	As a customer care executive, I want to generate reports on network performance for analysis.	User can create reports with specified parameters.	High	Sprint-3
		USN-16	As a customer care executive, I want to export reports in various formats (e.g., PDF, CSV).	User can export reports in requested formats.	Medium	Sprint-4
Administrator	User Management	USN-17	As an administrator, I want to manage user accounts (create, edit, delete) on the platform.	Administrator can create, edit, and delete user accounts.	High	Sprint-1
		USN-18	As an administrator, I want to grant or revoke access permissions to specific functionalities.	Administrator can manage user access permissions.	Medium	Sprint-2
	System Configuration	USN-19	As an administrator, I want to configure system settings and parameters for optimization.	Administrator can modify and save system configurations.	High	Sprint-1
		USN-20	As an administrator, I want to view system logs and user activity for auditing purposes.	Administrator can access and review system logs.	Medium	Sprint-3

6. PROJECT PLANNING & SCHEDULING

6.1. Technical Architecture



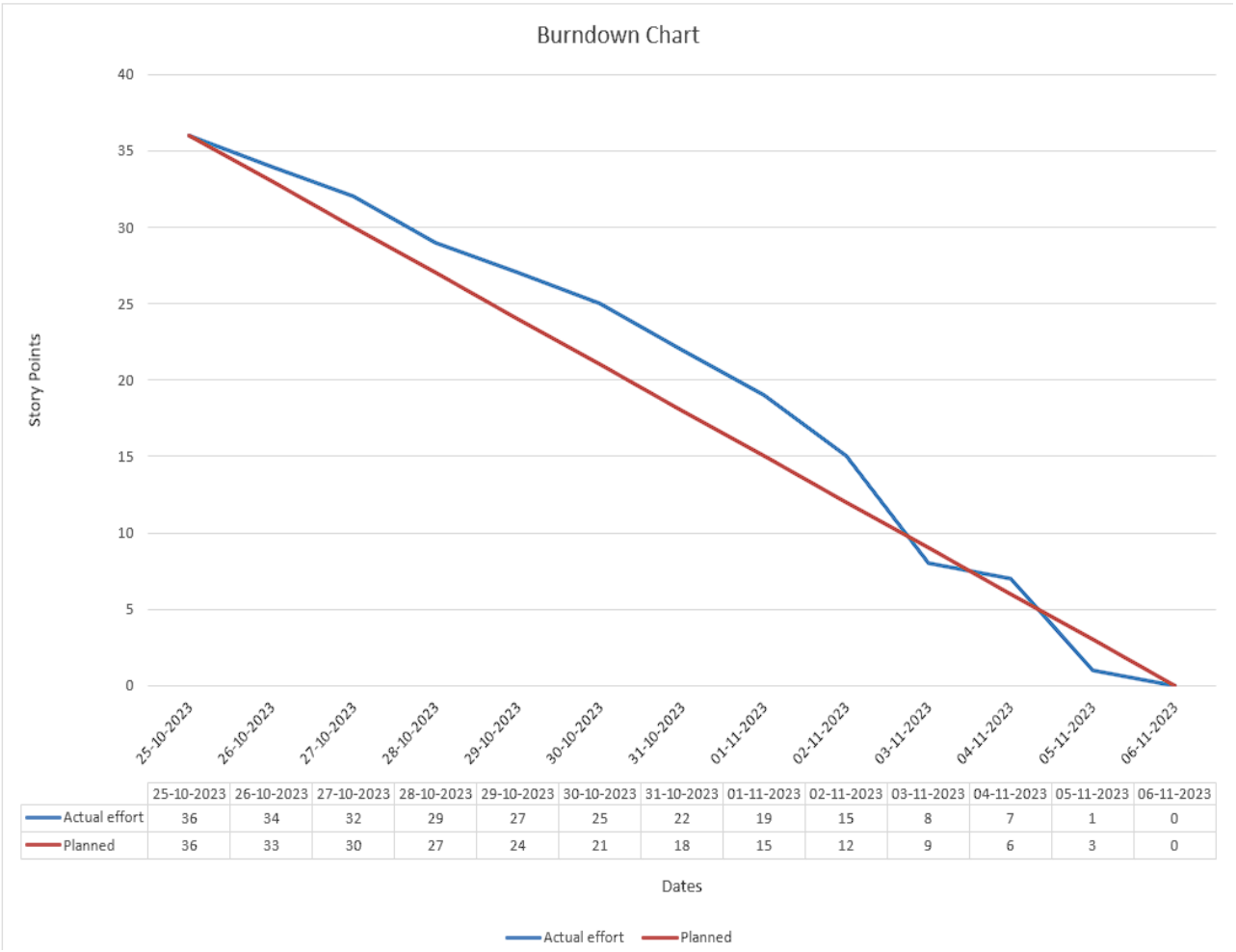
6.2. Sprint Planning & Estimation

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Priority	Story Points	Team Members
Sprint-1	Registration	USN-1	As a user, I want to register on the 5G optimization platform.	2	High	Isha
Sprint-2	Registration	USN-2	As a registered user, I want to reset my password.	1	Medium	Aditya
Sprint-1	Login	USN-3	As a user, I want to log in to the 5G optimization platform.	2	High	Vishnu
Sprint-2	Login	USN-4	As a logged-in user, I want to log out securely.	1	Medium	Isha
Sprint-1	Dashboard	USN-5	As a user, I want to view a dashboard with network metrics.	3	High	Aditya
Sprint-3	Dashboard	USN-6	As a user, I want to customize my dashboard.	1	Medium	Vishnu
Sprint-1	Registration	USN-7	As a user, I want to register on the 5G optimization platform.	2	High	Isha
Sprint-2	Registration	USN-8	As a registered user, I want to reset my password.	1	Medium	Aditya
Sprint-1	Login	USN-9	As a user, I want to log in to the 5G optimization platform.	2	High	Vishnu
Sprint-2	Login	USN-10	As a logged-in user, I want to log out securely.	1	Medium	Isha
Sprint-1	Dashboard	USN-11	As a user, I want to view a dashboard with network metrics.	3	High	Aditya
Sprint-3	Dashboard	USN-12	As a user, I want to customize my dashboard.	1	Medium	Vishnu
Sprint-1	Dashboard	USN-13	As a customer care executive, I want access to a dashboard.	2	High	Isha
Sprint-2	Dashboard	USN-14	As a customer care executive, I want to view network metrics.	2	Medium	Aditya
Sprint-3	Reporting	USN-15	As a customer care executive, I want to generate network reports.	3	High	Vishnu
Sprint-3	Reporting	USN-16	As a customer care executive, I want to export reports.	1	Medium	Isha
Sprint-1	User Management	USN-17	As an administrator, I want to manage user accounts.	2	High	Aditya
Sprint-2	User Management	USN-18	As an administrator, I want to control user access.	2	Medium	Vishnu
Sprint-1	System Configuration	USN-19	As an administrator, I want to configure system settings.	3	High	Isha
Sprint-3	System Configuration	USN-20	As an administrator, I want to view system logs.	1	Medium	Aditya

6.3. Sprint Delivery Schedule

Sprint	Total Story Points	Duration	Sprint Start Date	Sprint End Date (Planned)	Story Points Completed (as on Planned End Date)	Sprint Release Date (Actual)
Sprint-1	21	8 Days	26 Oct 2023	02 Nov 2023	21	02 Nov 2023
Sprint-2	8	2 Days	03 Nov 2023	04 Nov 2023	8	04 Nov 2023
Sprint-3	7	2 Days	05 Nov 2023	06 Nov 2023	7	06 Nov 2023

Burndown Chart:



	25-10-2023	26-10-2023	27-10-2023	28-10-2023	29-10-2023	30-10-2023	31-10-2023	01-11-2023	02-11-2023	03-11-2023	04-11-2023	05-11-2023	06-11-2023
Actual effort	36	34	32	29	27	25	22	19	15	8	7	1	0
Planned	36	33	30	27	24	21	18	15	12	9	6	3	0

7. CODING & SOLUTIONING

7.1. Feature 1 - Homepage (For User Login and Sign-up)

```
<!DOCTYPE html>
<html lang="en">
  <head>
    <!-- Required meta tags -->
    <meta charset="utf-8" />
    <meta
      name="viewport"
      content="width=device-width, initial-scale=1, shrink-to-fit=no"
    />

    <!-- Bootstrap CSS -->
    <link
      rel="stylesheet"
      href="https://cdn.jsdelivr.net/npm/bootstrap@4.3.1/dist/css/bootstrap.mi
n.css"
```

```
      integrity="sha384-
ggOyR0iXCbMQv3Xipma34MD+dH/1fQ784/j6cY/iJTQUOhcWr7x9JvoRxT2MZw1T"
      crossorigin="anonymous"
    />

    <title>5G ML APP</title>
  </head>
  <body style="background-color:aliceblue">
    <nav class="navbar navbar-expand-lg navbar-dark bg-dark">
      <a class="navbar-brand" href="/">5G ML APP</a>
      <button
        class="navbar-toggler"
        type="button"
        data-toggle="collapse"
        data-target="#navbarSupportedContent"
        aria-controls="navbarSupportedContent"
        aria-expanded="false"
        aria-label="Toggle navigation"
      >
        <span class="navbar-toggler-icon"></span>
      </button>

      <div class="collapse navbar-collapse" id="navbarSupportedContent">
        <ul class="navbar-nav mr-auto">
          <li class="nav-item active">
            <a class="nav-link" href="/"
             >Home <span class="sr-only">(current)</span>
            </a>
          </li>
          <li class="nav-item">
            <a class="nav-link" href="/about">About</a>
          </li>
          <li class="nav-item">
            <a class="nav-link" href="/pred">Prediction</a>
          </li>
        </ul>
        <div class="mx-2">
          <div
            class="btn btn-danger"
            data-toggle="modal"
            data-target="#LoginModal"
          >
            Login
          </div>
          <div
            class="btn btn-danger"
            data-toggle="modal"
            data-target="#SignUpModal"
```

```
          >
            Sign Up
          </div>
        </div>
      </div>
    </nav>

    <!--Login Modal -->
    <div
      class="modal fade"
      id="LoginModal"
      tabindex="-1"
      role="dialog"
      aria-labelledby="LoginModalLabel"
      aria-hidden="true"
    >
      <div class="modal-dialog" role="document">
        <div class="modal-content">
          <div class="modal-header">
            <h5 class="modal-title" id="LoginModalLabel">Login</h5>
            <button
              type="button"
              class="close"
              data-dismiss="modal"
              aria-label="Close"
            >
              <span aria-hidden="true">&times;</span>
            </button>
          </div>
          <div class="modal-body">
            <form>
                <div class="form-group">
                  <label for="exampleInputEmail1">Email address</label>
                  <input type="email" class="form-control"
id="exampleInputEmail1" aria-describedby="emailHelp" placeholder="Enter
email">
                  <small id="emailHelp" class="form-text text-muted">We'll
never share your email with anyone else.</small>
                </div>
                <div class="form-group">
                  <label for="exampleInputPassword1">Password</label>
                  <input type="password" class="form-control"
id="exampleInputPassword1" placeholder="Password">
                </div>
                <div class="form-group form-check">
                  <input type="checkbox" class="form-check-input"
id="exampleCheck1">
```

```
                <label class="form-check-label" for="exampleCheck1">I am a
User</label>
              </div>
              <button type="submit" class="btn btn-primary">Submit</button>
            </form>
          </div>
          <div class="modal-footer">
            <button
              type="button"
              class="btn btn-secondary"
              data-dismiss="modal"
            >
              Close
            </button>

          </div>
        </div>
      </div>
    </div>

    <!--SignUp Modal -->
    <div
      class="modal fade"
      id="SignUpModal"
      tabindex="-1"
      role="dialog"
      aria-labelledby="SignUpModalLabel"
      aria-hidden="true"
    >
      <div class="modal-dialog" role="document">
        <div class="modal-content">
          <div class="modal-header">
            <h5 class="modal-title" id="SignUpModalLabel">Get an account</h5>
            <button
              type="button"
              class="close"
              data-dismiss="modal"
              aria-label="Close"
            >
              <span aria-hidden="true">&times;</span>
            </button>
          </div>
          <div class="modal-body">
            <form>
                <div class="form-group">
                  <label for="exampleInputEmail1">Email address</label>
```

```
                <input type="email" class="form-control"
id="exampleInputEmail1" aria-describedby="emailHelp" placeholder="Enter
email">
                <small id="emailHelp" class="form-text text-muted">We'll
never share your email with anyone else.</small>
              </div>
              <div class="form-group">
                <label for="exampleInputPassword1">Password</label>
                <input type="password" class="form-control"
id="exampleInputPassword1" placeholder="Password">
              </div>
              <div class="form-group">
                  <label for="exampleInputPassword1">Confirm
Password</label>
                  <input type="password" class="form-control"
id="exampleInputPassword1" placeholder="Password">
                </div>
              <button type="submit" class="btn btn-primary">Create
Account</button>
            </form>
        </div>
        <div class="modal-footer">
          <button
            type="button"
            class="btn btn-secondary"
            data-dismiss="modal"
          >
            Close
        </div>
      </div>
    </div>
  </div>
  <div class="bd-example">
    <div
      id="carouselExampleCaptions"
      class="carousel slide carousel-fade"
      data-ride="carousel"
    >
      <ol class="carousel-indicators">
        <li
          data-target="#carouselExampleCaptions"
          data-slide-to="0"
          class="active"
        ></li>
        <li data-target="#carouselExampleCaptions" data-slide-to="1"></li>
        <li data-target="#carouselExampleCaptions" data-slide-to="2"></li>
      </ol>
      <div class="carousel-inner">
```

```
          <div class="carousel-item active">
            <img
              src="static\images\1.jpg"
              class="img-fluid"
              class="d-block w-100"
              alt="..."
              style="width: 100vw; height: 50vh"
            />
            <div class="carousel-caption d-none d-md-block">
              <h2>Welcome to the era of 5G</h2>
              <p>This website enables users to estimate the percentage of
resource that must be allocated to customers.</p>
            </div>
          </div>
          <div class="carousel-item">
            <img
              class="img-fluid"
              src="static\images\2.jpg"
              class="d-block w-100"
              alt="..."
              style="width: 100vw; height: 50vh"
            />
            <div class="carousel-caption d-none d-md-block">
              <h2>Extend your 5G services with us.</h2>
              <p>We will code to build awesome websites.</p>
            </div>
          </div>
          <div class="carousel-item">
            <img
              class="img-fluid"
              src="static\images\3.jpg"
              class="d-block w-100"
              alt="..."
              style="width: 100vw; height: 50vh"
            />
            <div class="carousel-caption d-none d-md-block">
              <h2>Grow with Us</h2>
              <p>Provide your 5G services accurately and efficiently.</p>
            </div>
          </div>
        </div>
        <a
          class="carousel-control-prev"
          href="#carouselExampleCaptions"
          role="button"
          data-slide="prev"
        >
          <span class="carousel-control-prev-icon" aria-hidden="true"></span>
```

```
          <span class="sr-only">Previous</span>
        </a>
        <a
          class="carousel-control-next"
          href="#carouselExampleCaptions"
          role="button"
          data-slide="next"
        >
          <span class="carousel-control-next-icon" aria-hidden="true"></span>
          <span class="sr-only">Next</span>
        </a>
      </div>
    </div>
    <div>
      <h2 style="padding: 6px 12px;">AI-Driven Optimization of 5G Resource
        Allocation for Network Efficiency.</h2>
        <h5 style="padding: 6px 12px;">Project Overview</h5>
        <p style="padding: 6px 12px;" style="flex: content justify-
content;">Our project is aimed at optimizing resource allocation in 5G
networks in India. India supports three types of 5G bands: low-band, mid-band,
and high-band (mm Wave), categorized by their frequencies. Simply put, the
higher the frequency, the better the speed and the shorter the network range.
We've developed a sophisticated machine learning model that takes key
parameters like Application Type, Signal Strength, Latency, Required
Bandwidth, and Allocated Bandwidth to predict efficient resource allocation.
By doing so, we aim to enhance the speed and reliability of 5G networks,
ensuring an improved user experience.</p>
        <h5 style="padding: 6px 12px;">Benefits</h5>
        <p>
          <ol>
            <li>
              <b>Enhanced Network Performance:</b> Our project ensures that 5G
networks perform at their best, offering users faster speeds and seamless
connectivity.
            </li>
            <li>
              <b>Optimized Resource Usage:</b> By intelligently allocating
resources based on various parameters, we minimize waste and maximize
efficiency.
            </li>
            <li>
              <b>Improved User Experience:</b> Users can expect a more
reliable and efficient 5G experience, whether for streaming, gaming, or work.
            </li>
            <li>
              <b>Future-Ready:</b> With 5G technology becoming increasingly
vital, our project is future-proof, aligning with the growing demands for
high-speed internet.
```

```
            </li>
            <li>
              <b>Data Privacy:</b> We prioritize data privacy, ensuring that
user information is kept secure and never shared with third parties.
            </li>
          </ol>
        </p>
    </div>
    <footer class="container"
    style="padding: 10px 0px 10px 0px;">
      <p class="float-right"><a href="#">Back to top</a></p>
      <p>
        Copyright © 2023 .  AI-Driven Optimization of 5G Resource
        Allocation for Network Efficiency.
      </p>
    </footer>
    <!-- Optional JavaScript -->
    <!-- jQuery first, then Popper.js, then Bootstrap JS -->
    <script
      src="https://code.jquery.com/jquery-3.3.1.slim.min.js"
      integrity="sha384-
q8i/X+965DzO0rT7abK41JStQIAqVgRVzpbzo5smXKp4YfRvH+8abtTE1Pi6jizo"
      crossorigin="anonymous"
    ></script>
    <script
      src="https://cdn.jsdelivr.net/npm/popper.js@1.14.7/dist/umd/popper.min.j
s"
      integrity="sha384-
UO2eT0CpHqdSJQ6hJty5KVphtPhzWj9WO1clHTMGa3JDZwrnQq4sF86dIHNDz0W1"
      crossorigin="anonymous"
    ></script>
    <script
      src="https://cdn.jsdelivr.net/npm/bootstrap@4.3.1/dist/js/bootstrap.min.
js"
      integrity="sha384-
JjSmVgyd0p3pXB1rRibZUAYoIIy6OrQ6VrjIEaFf/nJGzIxFDsf4x0xIM+B07jRM"
      crossorigin="anonymous"
    ></script>
  </body>
</html>
```

7.2. Feature 2 – About page

```
<!DOCTYPE html>
<html lang="en">
  <head>
    <!-- Required meta tags -->
```

```
    <meta charset="utf-8" />
    <meta
      name="viewport"
      content="width=device-width, initial-scale=1, shrink-to-fit=no"
    />

    <!-- Bootstrap CSS -->
    <link
      rel="stylesheet"
      href="https://cdn.jsdelivr.net/npm/bootstrap@4.3.1/dist/css/bootstrap.mi
n.css"
      integrity="sha384-
ggOyR0iXCbMQv3Xipma34MD+dH/1fQ784/j6cY/iJTQUOhcWr7x9JvoRxT2MZw1T"
      crossorigin="anonymous"
    />

    <title>5G ML APP</title>
  </head>
  <body style="background-color:aliceblue">
    <nav class="navbar navbar-expand-lg navbar-dark bg-dark">
      <a class="navbar-brand" href="/">5G ML APP</a>
      <button
        class="navbar-toggler"
        type="button"
        data-toggle="collapse"
        data-target="#navbarSupportedContent"
        aria-controls="navbarSupportedContent"
        aria-expanded="false"
        aria-label="Toggle navigation"
      >
        <span class="navbar-toggler-icon"></span>
      </button>

      <div class="collapse navbar-collapse" id="navbarSupportedContent">
        <ul class="navbar-nav mr-auto">
          <li class="nav-item">
            <a class="nav-link" href="/"
              >Home <span class="sr-only">(current)</span></a
            >
          </li>
          <li class="nav-item active">
            <a class="nav-link" href="#">About</a>
          </li>
          <li class="nav-item">
            <a class="nav-link" href="/pred">Prediction</a>
          </li>
        </ul>
      </div>
```

```
    </nav>
    <div class="container">
      <div
        class="row featurette d-flex justify-content-center align-items-center
my-4"
      >
        <div class="col-md-7">
          <h2 class="featurette-heading">About the project.....</h2>
          <p class="lead">
            We envision a world where 5G technology isn't just a buzzword but
an
            everyday reality, empowering individuals and businesses with
            lightning-fast, reliable, and efficient connectivity. We have
            developed a powerful machine learning model that optimizes
resource
            allocation in 5G networks. By understanding your unique
requirements
            and characteristics such as Application Type, Signal Strength,
            Latency, Required Bandwidth, and Allocated Bandwidth, we ensure
that
            you get the best out of your 5G connection.
          </p>
        </div>
        <div class="col-md-5">
          <img
            class="img-fluid"
            src="static/images/1.1.jpg"
            alt=""
            class="bd-placeholder-img bd-placeholder-img-lg featurette-image
img-fluid mx-auto"
            width="500"
            height="500"
          />
        </div>
      </div>
      <div
        class="row featurette d-flex justify-content-center align-items-center
my-4"
      >
        <div class="col-md-7 order-md-2">
          <h2 class="featurette-heading">Solution Architecture</h2>
          <p class="lead">
            The proposed solution architecture for AI-Driven Optimization of
5G
            Resource Allocation is a comprehensive framework designed to
bridge
            the gap between pressing business challenges in 5G network
            deployment and cutting-edge technology solutions. It follows a
```

```
            structured process that begins with the analysis of network
resource
            allocation issues and requirements gathering from stakeholders.
Data
            collection and preprocessing are crucial steps, ensuring the
            acquisition and preparation of relevant data, which is then used
for
            feature engineering and machine learning model development. Model
            evaluation and selection help identify the best-performing
algorithm
            for optimized resource allocation. A web-based user interface is
            created to provide users with secure access to the system,
offering
            reporting capabilities and data export for customer care
executives.
          </p>
        </div>

        <div class="col-md-5">
          <img
            class="img-fluid"
            src="static/images/1.2.png"
            alt=""
            class="bd-placeholder-img bd-placeholder-img-lg featurette-image
img-fluid mx-auto"
            width="500"
            height="500"
          />
        </div>
      </div>
      <div
        class="row featurette d-flex justify-content-center align-items-center
my-4"
      >
        <div class="col-md-7">
          <h2 class="featurette-heading">Technical Architecture</h2>
          <p class="lead">
            The technical architecture of the 5G ML Project seamlessly
            integrates various components to provide a robust and user-
friendly
            experience. It starts with user authentication and authorization,
            ensuring secure access for both users and administrators. Users
            enter specific parameters related to their resource allocation
            needs, which are then processed by a sophisticated machine
learning
            model. The predictions generated are stored in a database for
future
            reference. Our architecture prioritizes data security, with a
```

```
            dedicated database for storing user and admin credentials. The
user
            interface ties all these elements together, offering an intuitive
            platform for users to interact with the system, making resource
            allocation in 5G networks a hassle-free and efficient process.
          </p>
        </div>
        <div class="col-md-5">
          <img
            class="img-fluid"
            src="static/images/1.3.png"
            alt=""
            class="bd-placeholder-img bd-placeholder-img-lg featurette-image
img-fluid mx-auto"
            width="500"
            height="500"
          />
        </div>
      </div>
      <div
        class="row featurette d-flex justify-content-center align-items-center
my-4"
      >
        <div class="col-md-7 order-md-2">
          <h2 class="featurette-heading">Application Type</h2>
          <p class="lead">
            The "Application Type" feature in our 5G ML Project is a critical
            element that allows users to specify the nature of the
applications
            they intend to run on the 5G network. It caters to the diverse
            requirements of different applications, whether they are
streaming,
            gaming, IoT, or business-related. By accurately identifying the
            application type, our system can predict the most suitable
resource
            allocation, ensuring optimal network performance. This feature
            empowers users to tailor their 5G experience to the specific needs
            of their applications, guaranteeing a seamless and responsive
            network environment for a wide range of use cases.
            <b>Refer this table while doing predictions for best results.</b>
          </p>
        </div>

        <div class="col-md-5">
          <img
            class="img-fluid"
            src="static/images/1.4.jpg"
            alt=""
```

```
            class="bd-placeholder-img bd-placeholder-img-lg featurette-image
img-fluid mx-auto"
            width="300"
            height="300"
          />
        </div>
      </div>
    </div>
    <footer class="container" style="padding: 10px 0px 10px 0px">
      <p class="float-right"><a href="#">Back to top</a></p>
      <p>
        Copyright © 2023 . AI-Driven Optimization of 5G Resource Allocation
for
        Network Efficiency.
      </p>
    </footer>

    <!-- Optional JavaScript -->
    <!-- jQuery first, then Popper.js, then Bootstrap JS -->
    <script
      src="https://code.jquery.com/jquery-3.3.1.slim.min.js"
      integrity="sha384-
q8i/X+965DzO0rT7abK41JStQIAqVgRVzpbzo5smXKp4YfRvH+8abtTE1Pi6jizo"
      crossorigin="anonymous"
    ></script>
    <script
      src="https://cdn.jsdelivr.net/npm/popper.js@1.14.7/dist/umd/popper.min.j
s"
      integrity="sha384-
UO2eT0CpHqdSJQ6hJty5KVphtPhzWj9WO1clHTMGa3JDZwrnQq4sF86dIHNDz0W1"
      crossorigin="anonymous"
    ></script>
    <script
      src="https://cdn.jsdelivr.net/npm/bootstrap@4.3.1/dist/js/bootstrap.min.
js"
      integrity="sha384-
JjSmVgyd0p3pXB1rRibZUAYoIIy6OrQ6VrjIEaFf/nJGzIxFDsf4x0xIM+B07jRM"
      crossorigin="anonymous"
    ></script>
  </body>
</html>
```

7.3. Feature 3 – 5G resource allocation percentage Prediction page

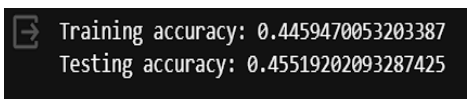
```
<!DOCTYPE html>
<html>
  <!-- Required meta tags -->
  <meta charset="utf-8" />
  <meta
    name="viewport"
    content="width=device-width, initial-scale=1, shrink-to-fit=no"
  />

  <!-- Bootstrap CSS -->
  <link
    rel="stylesheet"
    href="https://cdn.jsdelivr.net/npm/bootstrap@4.3.1/dist/css/bootstrap.min.
css"
    integrity="sha384-
ggOyR0iXCbMQv3Xipma34MD+dH/1fQ784/j6cY/iJTQUOhcWr7x9JvoRxT2MZw1T"
    crossorigin="anonymous"
  />
    <title>5G ML APP</title>
    <link
      href="https://fonts.googleapis.com/css?family=Pacifico"
      rel="stylesheet"
      type="text/css"
    />
    <link
      href="https://fonts.googleapis.com/css?family=Arimo"
      rel="stylesheet"
      type="text/css"
    />
    <link
      href="https://fonts.googleapis.com/css?family=Hind:300"
      rel="stylesheet"
      type="text/css"
    />
    <link
      href="https://fonts.googleapis.com/css?family=Open+Sans+Condensed:300"
      rel="stylesheet"
      type="text/css"
    />
    <link
      rel="stylesheet"
      href="{{ url_for('static', filename='css/style.css') }}"
    />


  </head>
```

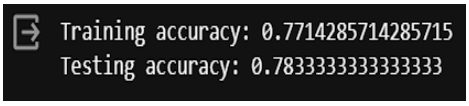
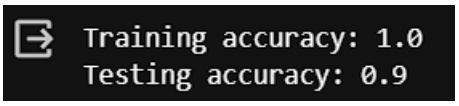
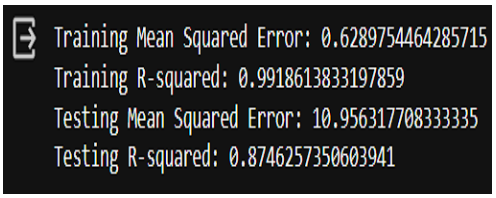
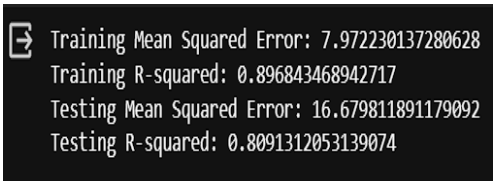
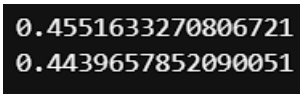
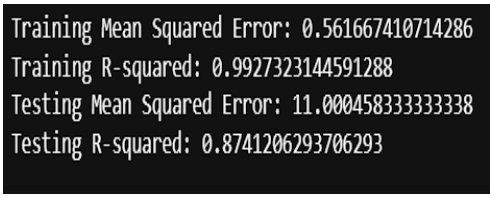
```
<body>
  <nav class="navbar navbar-expand-lg navbar-dark bg-dark">
    <a class="navbar-brand" href="/">5G ML APP</a>
    <button
      class="navbar-toggler"
      type="button"
      data-toggle="collapse"
      data-target="#navbarSupportedContent"
      aria-controls="navbarSupportedContent"
      aria-expanded="false"
      aria-label="Toggle navigation"
    >
      <span class="navbar-toggler-icon"></span>
    </button>

    <div class="collapse navbar-collapse" id="navbarSupportedContent">
      <ul class="navbar-nav mr-auto">
        <li class="nav-item">
          <a class="nav-link" href="/"
            >Home <span class="sr-only">(current)</span></a
          >
        </li>
        <li class="nav-item">
          <a class="nav-link" href="/about">About</a>
        </li>
        <li class="nav-item active">
          <a class="nav-link" href="/pred">Prediction</a>
        </li>
      </ul>
    </div>
  </nav>
  <div class="login">
    <h1>5G Resource Allocation</h1>

    <!-- Main Input For Receiving Query to our ML -->
    <form action="{{ url_for('prediction')}}" method="post" style="
    display:inline">
      <input
        type="text"
        name="Application_Type"
        placeholder="Enter ID of Application Type (Refer About Page)"
        required="required"
      />

      <input
        type="text"
        name="Signal_Strength"
        placeholder="Enter Signal Strength (in dbm)"
```

```
          required="required"
        />
        <input
          type="text"
          name="Latency"
          placeholder="Enter Latency (in ms)"
          required="required"
        />
        <input
          type="text"
          name="Required_Bandwidth(Kbps)"
          placeholder="Enter Required Bandwidth (in Kbps)"
          required="required"
        />
        <input
          type="text"
          name="Allocated_Bandwidth(Kbps)"
          placeholder="Enter Allocated_Bandwidth (in Kbps)"
          required="required"
        />

        <button type="submit" class="btn btn-primary btn-block btn-large">
          Predict
        </button>
      </form>
      <br />
      <br />
      {{ prediction_text }}
      <br/>
    </div>

  </body>

</html>
```

8. PERFORMANCE TESTING

8.1 Performance Metrics

S.No.	Parameter	Values	Screenshot
1.	Metrics	**Linear Regression Model:** Training accuracy: 0.4459470053203387 Testing accuracy: 0.45519202093287425	

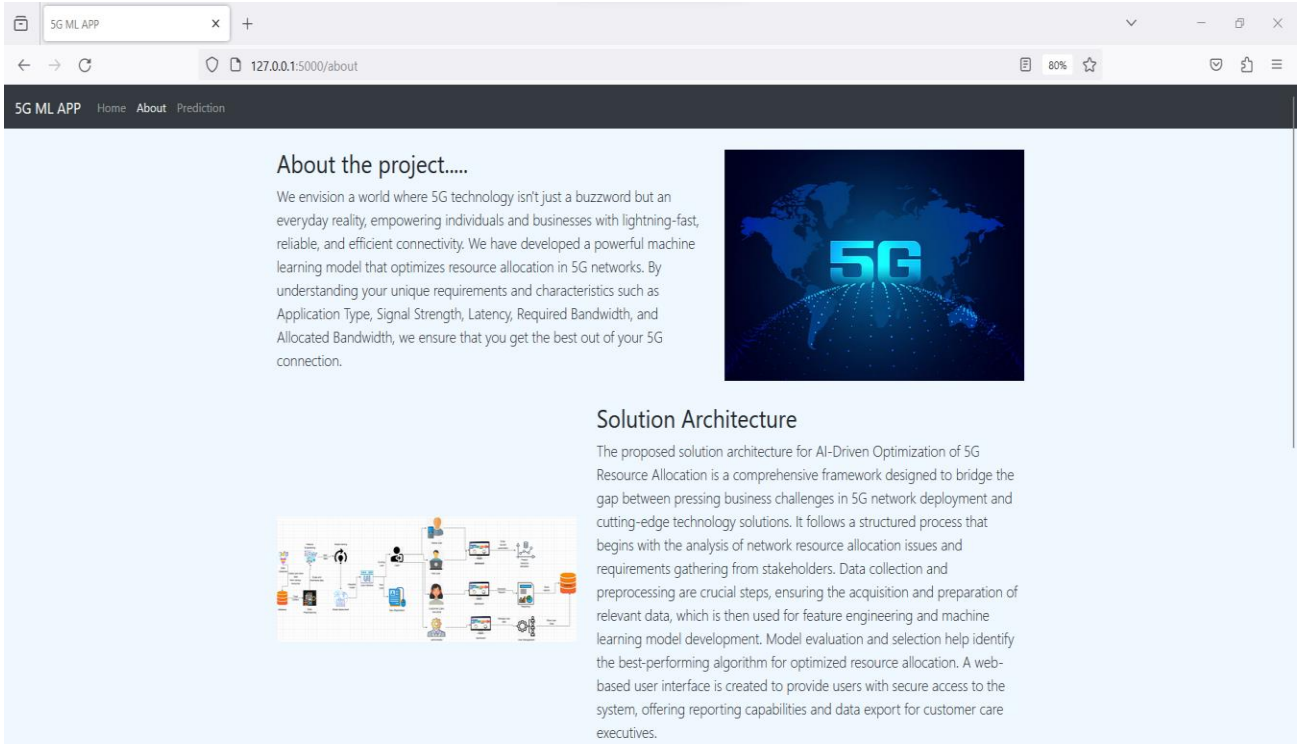
		Logistic Regression Model: Training accuracy: 0.7714285714285715 Testing accuracy: 0.7833333333333333	
		Decision Tree Regression Model: Training accuracy: 1.0 Testing accuracy: 0.9	
		Random Forest Regression Model (Best of ALL Models): Training MSE: 0.6289754464285715 Training R-squared: 0.9918613833197859 Testing MSE: 10.956317708333335 Testing R-squared: 0.8746257350603941	
		Polynomial Regression Model: Training MSE: 7.972230137280628 Training R-squared: 0.896843468942717 Testing MSE: 16.679811891179092 Testing R-squared: 0.8091312053139074	
		Lasso and Ridge Regression Model: Lasso accuracy: 0.4551633270806721 Ridge accuracy: 0.4439657852090051	
2.	Tune the Model	**Hyperparameter Tuning** Using Grid Search CV on Random Forest Model. Training MSE: 0.561667410714286 Training R-squared: 0.9927323144591288 Testing MSE: 11.000458333333338 Testing R-squared: 0.8741206293706293 **Validation** – There is no greater difference between the metrics of the original model and tuned model.	 **Hence the model is valid**.

9. RESULTS

9.1. Output Screenshots

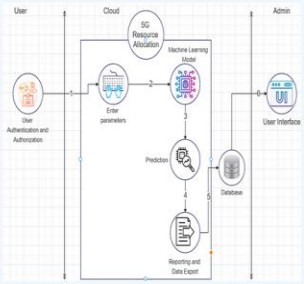
Homepage

About



Technical Architecture

The technical architecture of the 5G ML Project seamlessly integrates various components to provide a robust and user-friendly experience. It starts with user authentication and authorization, ensuring secure access for both users and administrators. Users enter specific parameters related to their resource allocation needs, which are then processed by a sophisticated machine learning model. The predictions generated are stored in a database for future reference. Our architecture prioritizes data security, with a dedicated database for storing user and admin credentials. The user interface ties all these elements together, offering an intuitive platform for users to interact with the system, making resource allocation in 5G networks a hassle-free and efficient process.



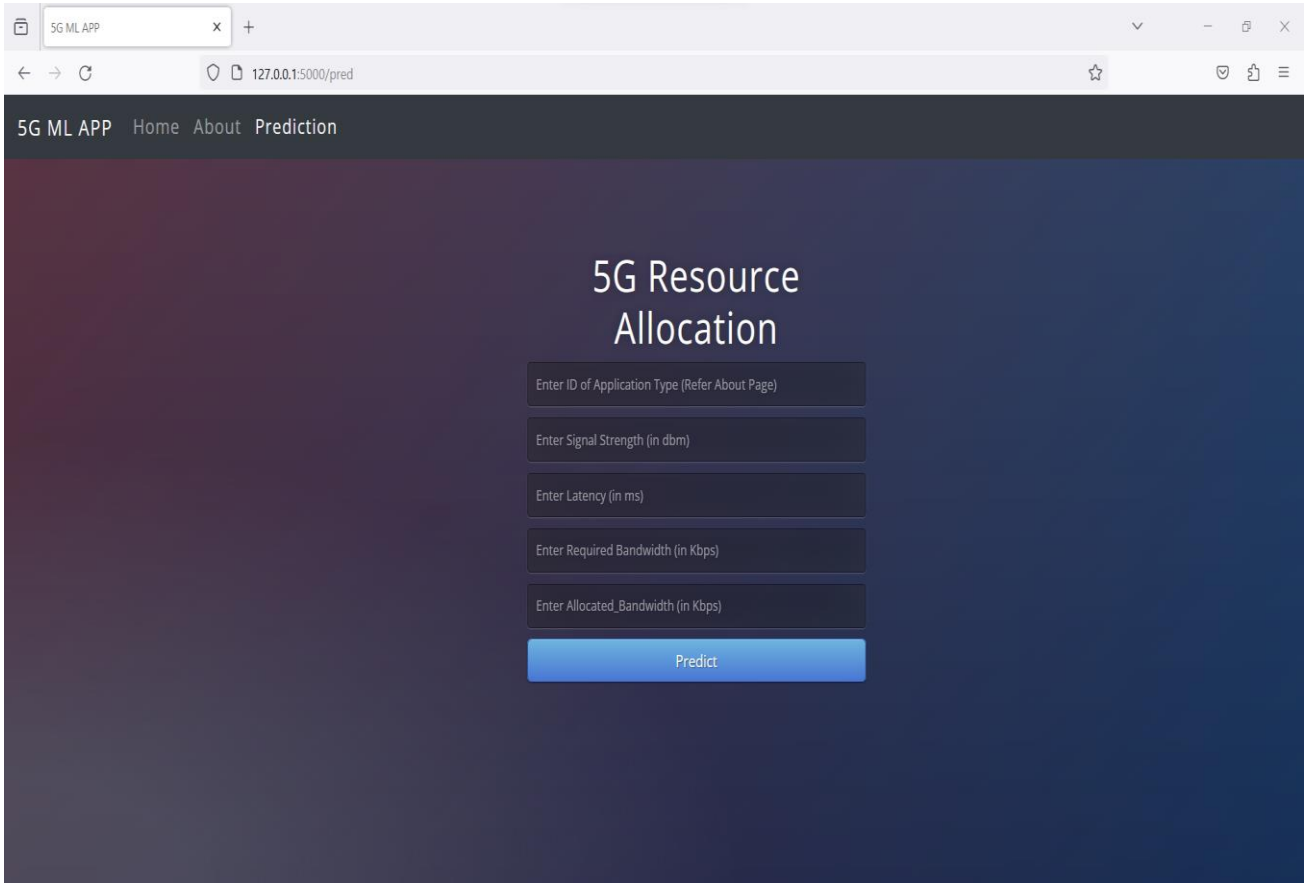
Application Type	ID
Background Download	0
Emergency Service	1
File Download	2
IoT Temperature	3
Online Gaming	4
Streaming	5
Video Call	6
Video Streaming	7
Voice Call	9
VoIP Call	8
Web Browsing	10

Application Type

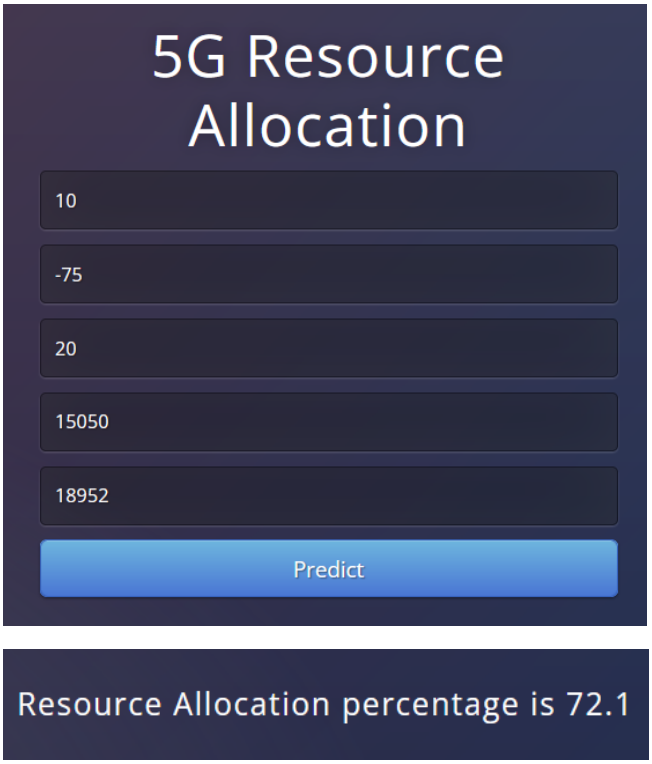
The "Application Type" feature in our 5G ML Project is a critical element that allows users to specify the nature of the applications they intend to run on the 5G network. It caters to the diverse requirements of different applications, whether they are streaming, gaming, IoT, or business-related. By accurately identifying the application type, our system can predict the most suitable resource allocation, ensuring optimal network performance. This feature empowers users to tailor their 5G experience to the specific needs of their applications, guaranteeing a seamless and responsive network environment for a wide range of use cases. **Refer this table while doing predictions for best results.**

Back to top

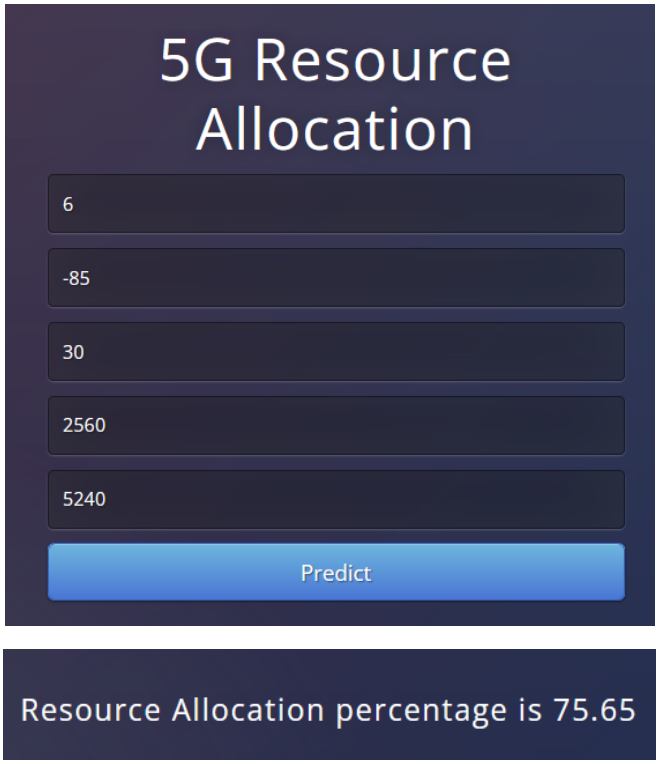
Prediction page



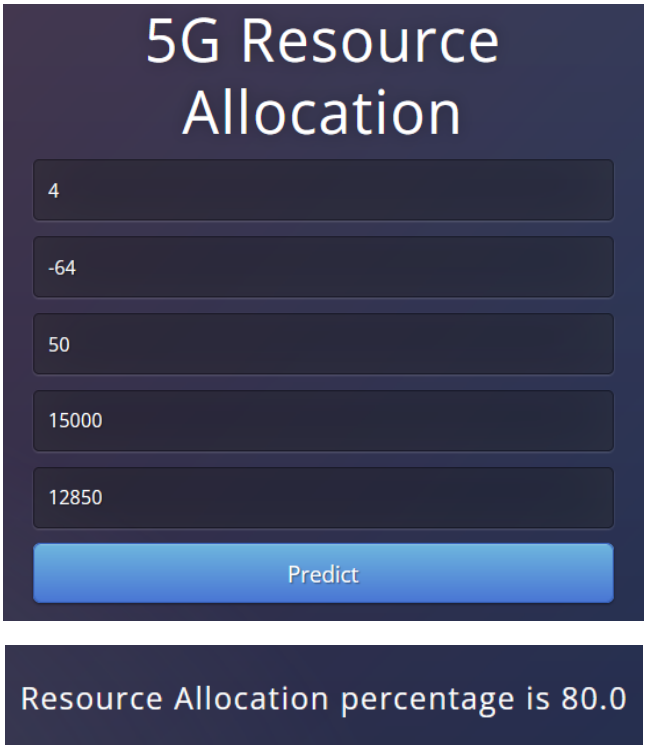
Prediction for Random Input 1:



Prediction for Random Input 2:



Prediction for Random Input 3:



10. ADVANTAGES & DISADVANTAGES

Advantages:

1. **Enhanced Network Efficiency:** The AI-driven optimization of 5G resource allocation can significantly enhance network efficiency by dynamically allocating resources based on real-time requirements. This leads to improved network performance and reduced latency.
2. **Cost Savings:** Efficient resource allocation ensures that resources are used optimally. This can lead to cost savings for network operators by reducing the need for over-provisioning and minimizing wasted resources.
3. **Improved User Experience:** Users benefit from faster network speeds and reduced latency, resulting in a better overall experience for applications such as video streaming, online gaming, and IoT devices.
4. **Network Scalability:** The project can help in scaling the network to accommodate more devices and users while maintaining a high-quality connection, addressing the challenges of the growing number of connected devices.
5. **Real-time Adaptation:** The AI-driven system can adapt in real-time to changing network conditions and application demands, ensuring that critical services receive the necessary resources when needed.

Disadvantages:

1. **Complex Implementation:** Developing and implementing AI-driven resource allocation systems can be complex and may require significant expertise in machine learning and network management.
2. **Data Privacy Concerns:** The project involves the collection and analysis of user data. Privacy concerns may arise if not handled carefully, leading to potential legal and ethical issues.
3. **Initial Setup Costs:** Setting up the infrastructure, including AI models and data collection mechanisms, can incur initial costs for network operators.
4. **Maintenance and Updates:** AI models require continuous monitoring, maintenance, and updates to remain effective. Neglecting this aspect can lead to performance degradation.
5. **Integration Challenges:** Integrating the AI-driven system with existing network infrastructure and protocols may present challenges that need to be addressed to ensure smooth operation.
6. **Resource Constraints:** The project may require significant computational resources for training and deploying AI models, which could strain existing infrastructure.

11. CONCLUSION

In conclusion, the project, "AI-Driven Optimization of 5G Resource Allocation for Network Efficiency," represents a significant advancement in the field of telecommunications and network management. By harnessing the power of artificial intelligence and machine learning, this project aims to address the growing demands on 5G networks and the need for efficient resource allocation. The advantages of improved network efficiency, cost savings, enhanced user experiences, and real-time adaptability are promising outcomes.

However, it is crucial to remain mindful of the challenges associated with complex implementation, data privacy concerns, and the need for ongoing maintenance and updates. These challenges highlight the importance of a well-thought-out strategy and the engagement of experts in the fields of machine learning and network management.

As the world becomes increasingly reliant on high-speed connectivity and the Internet of Things, the successful execution of this project has the potential to revolutionize 5G network operations. It is not merely a technological endeavor but also a step towards ensuring that our networks can keep up with the demands of the digital age, ultimately benefiting both network operators and end-users alike. The AI-driven optimization of 5G resource allocation is not just a project; it's a visionary step towards a more efficient and connected future.

12. FUTURE SCOPE

The future scope of the "AI-Driven Optimization of 5G Resource Allocation for Network Efficiency" project is promising and multifaceted. As 5G technology continues to evolve, the project can expand its capabilities to adapt to emerging network requirements. The integration of 5G with technologies like edge computing, IoT, and smart cities presents opportunities for further optimization. Additionally, the project can diversify its applications beyond telecommunications, such as in healthcare, autonomous vehicles, and industrial automation. Continuous improvements in machine learning algorithms and data analytics will enable more precise resource allocation, while addressing cybersecurity and data privacy concerns. Collaborations with industry leaders and academia can drive innovation, making this project a cornerstone for the dynamic future of 5G networks.

13. APPENDIX

Source Code

5g_resource_allocation.py (Machine Learning Code)

```
# -*- coding: utf-8 -*-
"""5G_Resource_Allocation.ipynb

Automatically generated by Colaboratory.

Original file is located at
    https://colab.research.google.com/drive/1QGunoJXjfa485yZ5Eq9sqZD4D7kpLyCV

Importing required libraries
"""

import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns

"""### Data Collection and Preprocessing

Reading Dataset
"""

df = pd.read_csv('/content/Quality of Service 5G.csv')
df.head()

df.shape

df.info()

"""Handling Missing Values
```

```
"""

df.isnull().sum()

"""Note : There are no missing values in the dataset

Removing unwanted features (User_ID and Timestamp)
"""

new_df = df.drop(['Timestamp', 'User_ID'], axis=1)
new_df.head()

"""Handling Categorical Columns (Label Encoding)"""

new_df.Application_Type.nunique()

new_df.Application_Type.value_counts()

from sklearn.preprocessing import LabelEncoder
le = LabelEncoder()
new_df['Application_Type'] = le.fit_transform(new_df['Application_Type'])
new_df.head()

data = pd.DataFrame({'index':[0,1,2,3,4,5,6,7,8,9,10],
        'Application_Type':['Video_Call','Web_Browsing','Streaming','Emergency
_Service','Background_Download','Video_Streaming','VoIP_Call','Online_Gaming',
'IoT_Temperature','Voice_Call','File_Download']})
data['ID'] = le.fit_transform(data['Application_Type'].values)
data = data.drop_duplicates('Application_Type').set_index('index')
print(data)

"""Regex Clenaing"""

# Removing units of Signal_Strength, Latenecy, Resource Allocation

new_df['Signal_Strength'] =
new_df['Signal_Strength'].str.extract('(\d+)').astype(int)
new_df['Latency'] = new_df['Latency'].str.extract('(\d+)').astype(int)
new_df['Resource_Allocation'] =
new_df['Resource_Allocation'].str.extract('(\d+)').astype(int)

new_df.head()

"""Converting units from Mbps to Kbps"""

new_df[['Size','Unit']] = new_df.Allocated_Bandwidth.str.split(' ',
expand=True)
```

```
new_df['Size'] = new_df.Size.astype(float)
new_df.Unit.replace({'Mbps': 1024, 'Kbps': 1}, inplace=True)
new_df['Allocated_Bandwidth(Kbps)'] = new_df.Size * new_df.Unit

new_df[['Size1','Unit1']] = new_df.Required_Bandwidth.str.split(' ',
expand=True)
new_df['Size1'] = new_df.Size1.astype(float)
new_df.Unit1.replace({'Mbps': 1024, 'Kbps': 1}, inplace=True)
new_df['Required_Bandwidth(Kbps)'] = new_df.Size1 * new_df.Unit1

new_df.head()

new_df.drop(columns='Size',inplace=True)
new_df.drop(columns='Unit',inplace=True)

new_df.drop(columns='Size1',inplace=True)
new_df.drop(columns='Unit1',inplace=True)

new_df.drop(columns='Allocated_Bandwidth',inplace=True)
new_df.drop(columns='Required_Bandwidth',inplace=True)

new_df.head()

"""Descriptive Analytics"""

new_df.describe()

"""Handling Outliers"""

sns.boxplot(new_df.Application_Type)

"""Note : There are no outliers in Application_Type feature."""

sns.boxplot(new_df.Signal_Strength)

"""Note : There are no outliers in Signal_Strength feature."""

sns.boxplot(new_df.Latency)

# Replacing outliers in Latencey with median of Latency

q1 = new_df.Latency.quantile(0.25) #Q1
q3 = new_df.Latency.quantile(0.75) #Q3
print(q1)
print(q3)

IQR = q3 - q1
print(IQR)
```

```
upper_limit = q3+(1.5)*(IQR)
lower_limit = q1-(1.5)*(IQR)
print(upper_limit)
print(lower_limit)

new_df.Latency.median()

new_df['Latency'] = np.where(new_df['Latency'] > upper_limit,
new_df.Latency.median(), new_df['Latency'])
sns.boxplot(new_df.Latency)

"""Note : Outliers in Latency column are replaced using Median of Latency"""

# Replacing outliers in Allocated_Bandwidth(Kbps) with median

q1_AB = new_df['Allocated_Bandwidth(Kbps)'].quantile(0.25) #Q1
q3_AB = new_df['Allocated_Bandwidth(Kbps)'].quantile(0.75) #Q3
print(q1_AB)
print(q3_AB)

IQR_AB = q3_AB - q1_AB
print(IQR_AB)

upper_limit_AB = q3_AB+(1.5)*(IQR_AB)
lower_limit_AB = q1_AB-(1.5)*(IQR_AB)
print(upper_limit_AB)
print(lower_limit_AB)

new_df['Allocated_Bandwidth(Kbps)'].median()

new_df['Allocated_Bandwidth(Kbps)'] =
np.where(new_df['Allocated_Bandwidth(Kbps)'] > upper_limit_AB,
new_df['Allocated_Bandwidth(Kbps)'].median(),
new_df['Allocated_Bandwidth(Kbps)'])
sns.boxplot(new_df['Allocated_Bandwidth(Kbps)'])

"""Note : Outliers in Allocated_Bandwidth(Kbps) column are replaced using
Median"""

sns.boxplot(new_df['Required_Bandwidth(Kbps)'])

# Replacing outliers in Allocated_Bandwidth(Kbps) with median

q1_RB = new_df['Required_Bandwidth(Kbps)'].quantile(0.25) #Q1
q3_RB = new_df['Required_Bandwidth(Kbps)'].quantile(0.75) #Q3
print(q1_RB)
print(q3_RB)
```

```
IQR_RB = q3_RB - q1_RB
print(IQR_RB)

new_df['Required_Bandwidth(Kbps)'].median()

upper_limit_RB = q3_RB+(1.5)*(IQR_RB)
lower_limit_RB = q1_RB-(1.5)*(IQR_RB)
print(upper_limit_RB)
print(lower_limit_RB)

new_df['Required_Bandwidth(Kbps)'] =
np.where(new_df['Required_Bandwidth(Kbps)'] > upper_limit_RB,
new_df['Required_Bandwidth(Kbps)'].median(),
new_df['Required_Bandwidth(Kbps)'])
sns.boxplot(new_df['Required_Bandwidth(Kbps)'])

"""Note : Outliers in Required_Bandwidth(Kbps) column are replaced using
Median

### Data Visualisation
"""

import plotly.express as px

"""Visualising Latency by Application_Type"""

plt.figure(figsize=(12, 6))
sns.barplot(x='Application_Type', y='Latency', data=new_df)
plt.title('Latency by Application Type')
plt.xticks(rotation=45)
plt.show()

"""Visualize Signal_Strength by Application_Type"""

plt.figure(figsize=(12, 6))
sns.barplot(x='Application_Type', y='Signal_Strength', data=new_df)
plt.title('Signal Strength by Application Type')
plt.xticks(rotation=45)
plt.show()

"""Visualising distribution of Application Types"""

plt.figure(figsize=(10, 6))
sns.countplot(data=df, x='Application_Type')
plt.title('Distribution of Application Types')
plt.xticks(rotation=45)
plt.xlabel('Application Type')
```

```
plt.ylabel('Count')
plt.show()

"""Most Commonly Used Application Types

"""

application_counts = df['Application_Type'].value_counts()
application_counts

plt.figure(figsize=(10, 6))
sns.barplot(x=application_counts.index, y=application_counts.values,
palette="viridis")
plt.title('Most Commonly Used Application Types')
plt.xlabel('Application Type')
plt.ylabel('Count')
plt.xticks(rotation=90)
plt.show()

"""Distribution of Resource Allocation"""

plt.figure(figsize=(10, 6))
sns.histplot(data=new_df, x='Resource_Allocation', bins=10 ,kde=True)
plt.title('Distribution of Resource Allocation')
plt.xlabel('Resource Allocation (%)')
plt.ylabel('Count')
plt.show()

"""Distribution of Signal Strength"""

plt.figure(figsize=(10, 12))
sns.histplot(data=new_df, x='Signal_Strength', bins=20, kde=True)
plt.title('Distribution of Signal Strength')
plt.xlabel('Signal Strength')
plt.ylabel('Frequency')
plt.show()

"""Correlation between Signal Strength and Allocated Bandwidth"""

plt.figure(figsize=(8, 6))
sns.scatterplot(data=new_df, x='Signal_Strength',
y='Allocated_Bandwidth(Kbps)',)
plt.title('Correlation Between Signal Strength and Allocated Bandwidth')
plt.xlabel('Signal Strength')
plt.ylabel('Allocated Bandwidth')
plt.grid(True)
plt.show()
```

```
"""Relationship between Allocated Bandwidth and Required Bandwidth"""

plt.figure(figsize=(8, 6))
sns.scatterplot(data=new_df, x='Required_Bandwidth(Kbps)',
y='Allocated_Bandwidth(Kbps)')
plt.title('Relationship Between Allocated Bandwidth and Required Bandwidth')
plt.xlabel('Required Bandwidth')
plt.ylabel('Allocated Bandwidth')
plt.grid(True)
plt.show()

"""Top 8 application using high latency"""

app_name = df.Application_Type.value_counts().index
lat_val = df.Latency.value_counts().values
plt.pie(lat_val[:7],labels = app_name[:7],autopct='%1.f%%');

new_df.corr()

plt.figure(figsize=(10,8))
sns.heatmap(new_df.corr(),annot =True)

"""### X and Y splits"""

Y=new_df['Resource_Allocation']
Y

X=new_df.drop(columns=['Resource_Allocation'],axis=1)
X

"""### Train and Test splits"""

from sklearn.model_selection import train_test_split
X_train,X_test,Y_train,Y_test =
train_test_split(X,Y,test_size=0.3,random_state=42)

X_train.shape

X_test.shape

"""### Model Building

1. Linear regression
"""

from sklearn.linear_model import LinearRegression
model = LinearRegression()
model.fit(X_train,Y_train)
```

```
Y_pred =model.predict(X_test)
Y_pred

res = pd.DataFrame({'Actual Resource Allocated':Y_test,'Predictd Resource
Allocation':Y_pred})
res

"""2. Logistic regression"""

from sklearn.linear_model import LogisticRegression
model2 = LogisticRegression()
model2.fit(X_train,Y_train)
Y_pred_2 =model2.predict(X_test)
Y_pred_2

res_2 = pd.DataFrame({'Actual Resource Allocated':Y_test,'Predictd Resource
Allocation':Y_pred_2})
res_2

"""3. Decision-Tree regressor"""

from sklearn.tree import DecisionTreeRegressor

model3 = DecisionTreeRegressor()
model3.fit(X_train,Y_train)
Y_pred_3 =model3.predict(X_test)
Y_pred_3

res_3 = pd.DataFrame({'Actual Resource Allocated':Y_test,'Predictd Resource
Allocation':Y_pred_3})
res_3

"""4. Random Forest Regressor"""

from sklearn.ensemble import RandomForestRegressor
model4 = RandomForestRegressor(n_estimators=200)
model4.fit(X_train,Y_train)
Y_pred_4 =model4.predict(X_test)
Y_pred_4

res_4 = pd.DataFrame({'Actual Resource Allocated':Y_test,'Predictd Resource
Allocation':Y_pred_4})
res_4

"""5. Polynomial regression"""

from sklearn.preprocessing import PolynomialFeatures
from sklearn.linear_model import LinearRegression
```

```
from sklearn.pipeline import make_pipeline
degree = 2
model5 = make_pipeline(PolynomialFeatures(degree), LinearRegression())
model5.fit(X_train,Y_train)
Y_pred_5 =model5.predict(X_test)
Y_pred_5

res_5 = pd.DataFrame({'Actual Resource Allocated':Y_test,'Predictd Resource
Allocation':Y_pred_5})
res_5

"""6. Ridge and Lasso regression"""

from sklearn.linear_model import Ridge
from sklearn.linear_model import Lasso

r = Ridge()
l = Lasso()

r.fit(X_train,Y_train)

Y_pred_6 =r.predict(X_test)
Y_pred_6

res_6 = pd.DataFrame({'Actual Resource Allocated':Y_test,'Predictd Resource
Allocation':Y_pred_6})
res_6

l.fit(X_train,Y_train)
Y_pred_7 =l.predict(X_test)
Y_pred_7

res_7 = pd.DataFrame({'Actual Resource Allocated':Y_test,'Predictd Resource
Allocation':Y_pred_7})
res_7

"""### Performance Testing"""

from sklearn import metrics
from sklearn.metrics import accuracy_score, confusion_matrix
,classification_report

"""1. Linear Regression"""

Y_pred_train =model.predict(X_train)
print("Training accuracy:", metrics.r2_score(Y_train, Y_pred_train))
print("Testing accuracy:", metrics.r2_score(Y_test, Y_pred))
```

```
"""2. Logistic regression"""

Y_pred_2_train =model2.predict(X_train)
print("Training accuracy:", accuracy_score(Y_train, Y_pred_2_train))
print("Testing accuracy:", accuracy_score(Y_test, Y_pred_2))

# Classification report for Logistic Regression

import warnings
warnings.filterwarnings("ignore", category=UserWarning)
print(classification_report(Y_test, Y_pred_2))

"""3. Decision-Tree Regressor"""

Y_pred_3_train =model3.predict(X_train)
print("Training accuracy:", accuracy_score(Y_train, Y_pred_3_train))
print("Testing accuracy:", accuracy_score(Y_test, Y_pred_3))

# Classification report for Decision-Tree Regressor

warnings.filterwarnings("ignore", category=UserWarning)
print(classification_report(Y_test, Y_pred_3))

"""4. Random Forest Regressor"""

from sklearn.metrics import mean_squared_error, r2_score

# Training Accuracy
Y_pred_4_train = model4.predict(X_train)
train_mse = mean_squared_error(Y_train, Y_pred_4_train)
train_r2 = r2_score(Y_train, Y_pred_4_train)

# Testing Accuracy
test_mse = mean_squared_error(Y_test, Y_pred_4)
test_r2 = r2_score(Y_test, Y_pred_4)

print("Training Mean Squared Error:", train_mse)
print("Training R-squared:", train_r2)
print("Testing Mean Squared Error:", test_mse)
print("Testing R-squared:", test_r2)

"""5. Polynomial regression"""

# Training Accuracy
Y_pred_5_train = model5.predict(X_train)
train_mse_1 = mean_squared_error(Y_train, Y_pred_5_train)
train_r2_1 = r2_score(Y_train, Y_pred_5_train)
```

```
# Testing Accuracy
test_mse_1 = mean_squared_error(Y_test, Y_pred_5)
test_r2_1 = r2_score(Y_test, Y_pred_5)

print("Training Mean Squared Error:", train_mse_1)
print("Training R-squared:", train_r2_1)
print("Testing Mean Squared Error:", test_mse_1)
print("Testing R-squared:", test_r2_1)

"""6. Lasso and Ridge Regression"""

print(metrics.r2_score(Y_test,Y_pred_6))
print(metrics.r2_score(Y_test,Y_pred_7))

"""Note: Random Forest Regressor is found to be the best model with "Training
r2-score : 99.18%" and "Testing r2-score : 87.46%"

### Model Deployment
"""

import pickle
pickle.dump(model4,open('5G_Quality.pkl','wb'))

"""### Testing with random values

"""

model4.predict([[6,85,30,2560,5240]])

model4.predict([[10,75,20,15050,18952]])

model4.predict([[2,75,20,20,58]])

"""### Tuning Model"""

from sklearn.model_selection import GridSearchCV

param_grid = {
    'n_estimators': [100, 200, 300],  # Number of trees in the forest
    'max_depth': [None, 10, 20, 30],  # Maximum depth of the trees
    'min_samples_split': [2, 5, 10],  # Minimum number of samples required to
split an internal node
    'min_samples_leaf': [1, 2, 4],  # Minimum number of samples required to be
a leaf node
}

grid_search = GridSearchCV(estimator=model4, param_grid=param_grid, cv=5,
scoring='neg_mean_squared_error', n_jobs=-1)
```

```
grid_search.fit(X_train, Y_train)

print("Best hyperparameters:", grid_search.best_params_)
print("Best score:", -grid_search.best_score_)

from sklearn.ensemble import RandomForestRegressor
params = {
    'max_depth': 20,
    'min_samples_leaf': 1,
    'min_samples_split': 2,
    'n_estimators': 200
}
model4_tuned = RandomForestRegressor(**params)
model4_tuned.fit(X_train,Y_train)
Y_pred_4_tuned =model4_tuned.predict(X_test)
Y_pred_4_tuned

res_4_tuned = pd.DataFrame({'Actual Resource Allocated':Y_test,'Predictd
Resource Allocation':Y_pred_4_tuned})
res_4_tuned

from sklearn.metrics import mean_squared_error, r2_score

# Training Accuracy
Y_pred_4_train_tuned = model4.predict(X_train)
train_mse_tuned = mean_squared_error(Y_train, Y_pred_4_train_tuned)
train_r2_tuned = r2_score(Y_train, Y_pred_4_train_tuned)

# Testing Accuracy
test_mse_tuned = mean_squared_error(Y_test, Y_pred_4_tuned)
test_r2_tuned = r2_score(Y_test, Y_pred_4_tuned)

print("Training Mean Squared Error:", train_mse_tuned)
print("Training R-squared:", train_r2_tuned)
print("Testing Mean Squared Error:", test_mse_tuned)
print("Testing R-squared:", test_r2_tuned)
```

application.py (Flask Deployment Code)

```
import numpy as np
from flask import Flask, request, render_template
import pickle

application = Flask(__name__)  # Initialize the Flask App
model = pickle.load(open('5G_Quality.pkl', 'rb'))

@application.route('/')
```

```
def index():
    return render_template('index.html')

@application.route('/about')
def about():
    return render_template('about.html')

@application.route('/pred')  # Use a unique endpoint name, e.g., '/pred'
def pred():
    return render_template('pred.html')

@application.route('/prediction', methods=['POST'])
def prediction():
    '''
    For rendering results on HTML GUI
    '''
    int_features = [int(x) for x in request.form.values()]
    final_features = [np.array(int_features)]
    prediction = model.predict(final_features)

    output = round(prediction[0], 2)

    return render_template('pred.html', prediction_text='Resource Allocation
percentage is {}'.format(output))

if __name__ == "__main__":
    application.run(debug=True)
```

GitHub Repository Link:

https://github.com/smartinternz02/SI-GuidedProject-598588-1697615053/tree/main/Team-592348%20Project%20Development%20Phase

Project Demo Link:

https://drive.google.com/drive/folders/1ybEtS7hZ3ZbkkFo8SlYKc21BWFWJeA0n?usp=sharing