SCHOOL OF COMPUTER SCIENCE AND ENGINEERING

A Mini Project report on

Resource Allocation for T-NTN

Submitted

in partial fulfillment of the requirements for the award of the degree of

Bachelor of Engineering

IN

COMPUTER SCIENCE AND ENGINEERING

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CERTIFICATE

This is to certify that project entitled "Resource Allocation for T-NTN" is a bonafied work carried out by the student team (Akhilesh 01FE21BCS269, Gaurav Kiran V 01FE21BCS117, Nandan 01FE21BCS323, Ankith 01FE21BCS243), in partial fulfillment of the completion of 5th semester B. E. course during the year 2023 – 2024. The project report has been approved as it satisfies the academic requirement with respect to the project work prescribed for the above said course.

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ABSTRACT

The demand for efficient resource allocation in integrated Terrestrial-Non-Terrestrial Networks (T-NTN) has grown significantly with the advent of 5G NR technology.The aiming to enhance network performance, minimize costs, and ensure fair resource utilization. The proposed co-operative RRM scheme leverages multicast subgrouping techniques to optimize the allocation of radio resources, including spectrum, channels, bandwidth, time slots, power, and antenna resources. This systematic review critically assesses the existing literature on resource allocation strategies within Integrated Terrestrial/Non-Terrestrial (T-NTN) networks, focusing on their application in the context of 5G and emerging communication technologies. The review aims to identify key research trends, methodologies, challenges, and advancements in this domain, providing insights into the current state of knowledge and highlighting potential avenues for future research.

Keywords : *5G New Radio (NR) technology,RRM*

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Chapter 1

INTRODUCTION

To provide the promised performance improvement, current fifth-generation (5G) New Radio (NR) systems are called to answer the ever-growing demand for innovative services that require wide bandwidth and are consumed by an increasing number of smart devices.

In the pursuit of achieving unprecedented communication capabilities, the evolution of wireless networks has witnessed a paradigm shift towards the integration of terrestrial and non-terrestrial technologies. The synergy between terrestrial and non-terrestrial networks, often referred to as T-NTN, has emerged as a key enabler for meeting the diverse and demanding requirements of 5G and beyond communication systems.

The distinctive characteristics of terrestrial and non-terrestrial networks, such as low-latency terrestrial links and extensive coverage offered by satellites, can be harnessed together to create a seamless and efficient communication infrastructure. However, the effective utilization of resources in T-NTN poses significant challenges due to the heterogeneity of network components, varying propagation characteristics, and the need for cooperative resource allocation strategies.

Resource allocation, a critical aspect of network management, becomes particularly intricate in T-NTN environments. It involves judiciously distributing communication resources, such as bandwidth, power, and computing capacity, among different network entities to optimize overall performance. The integration of terrestrial and non-terrestrial elements introduces new dimensions to this challenge, demanding innovative solutions to ensure efficient utilization and maximize the benefits of both network types.

This paper explores the nuances of resource allocation in the context of T-NTN networks within the 5G and beyond landscape. We delve into the complexities associated with managing terrestrial and satellite resources, considering factors like diverse user requirements, mobility patterns, and dynamic network conditions. Furthermore, the paper investigates cooperative resource allocation strategies, aiming to enhance collaboration among network nodes, mitigate interference, and achieve an intelligent and adaptive allocation of resources. [?]

1.1 Overview of the NTN and T-NTN:

Terrestrial Networks: Terrestrial networks are communication systems that function on the earth's surface, using wired or wireless signals that pass through the atmosphere. They are the most common type of communication network, and include a wide range of technologies, such as landline telephone networks, Cellular networks Wi-Fi networks, broadband internet networks. Terrestrial networks are constantly evolving, with new technologies being developed all the time. For example, 5G cellular networks are expected to provide even faster data rates and lower latency than previous generations of cellular networks.

Non Terrestrial Networks: Non-terrestrial networks, also known as non-terrestrial networks (NTNs),refer to communication networks that do not rely exclusively on traditional terrestrial infrastructure, such as cell towers and land-based fiber-optic cables. Non-terrestrial networks (NTNs) are wireless communication systems that operate above the Earth's surface. They include satellites, high-altitude platforms (HAPS) and drones.

Integration with Terrestrial Networks: NTNs are increasingly being integrated with terrestrial networks to provide seamless connectivity to users. This is achieved through a variety of techniques, such as network slicing and multi-connectivity. This allows them to tailor the network to the specific needs of different applications and users. Multi-connectivity allows devices to connect to multiple networks simultaneously, which improves reliability and performance.

1.2 Motivation

Enabling Future Applications: Integrated terrestrial-non-terrestrial networks are fundamental for enabling future applications such as autonomous vehicles, immersive multimedia experiences etc.

Future Network Evolution: As the telecommunications industry moves towards 6G networks, it is crucial to develop innovative solutions that can adapt and evolve with future network technologies.

Multicast Service involve delivering data to multiple users simultaneously, are essential for applications like video streaming, online gaming, and real-time updates.

Improved Throughput and Fair Resource Allocation: efficiently allocating radio resources between terrestrial and non-terrestrial cells to improve overall network throughput while ensuring fair resource allocation.

1.3 Literature Review / Survey

Cooperative Resource Allocation in Integrated Terrestrial/Non-Terrestrial 5G and Beyond Networks, IEEE Access, 2020 New 5G technology can help combine satellite and ground networks to provide better coverage, reliability, and performance. Researchers proposed a new[1] way to combine satellite and ground networks to deliver multicast services more efficiently. The new method can improve network throughput and fairness for all users.

Dynamic Resource Optimization Allocation for 5G Network Slices Under Multiple Scenarios, IEEE Access, 2020 To optimize bandwidth resource allocation for multiple IoT scenarios in 5G, the authors propose a dynamic scheme based on SDN[2] with admission control and delay penalty factor. The scheme minimizes cost while meeting performance requirements. The authors propose a MIMO-NOMA network resource allocation algorithm based on user clustering to improve user experience quality by alleviating co-channel interference and guaranteeing QoS requirements.

Research on Resource Allocation and Optimization Technology in 5G Communication Network, IEEE Access, 2022 A new MIMO-NOMA network resource allocation algorithm based on user clustering is proposed to improve user experience quality and guarantee QoS requirements. The algorithm effectively alleviates co-channel interference and improves overall network performance. The authors propose a new MIMO-NOMA network resource allocation [3]algorithm based on user clustering to improve user experience quality and reduce computational complexity. The algorithm effectively alleviates co-channel interference and guarantees QoS requirements.

Resource Allocation for 5G URLLC in Cooperative Industrial Networks, IEEE Access, 2021 To meet the stringent latency and reliability requirements of URLLC in cooperative industrial networks, the authors propose a JRABA algorithm to jointly optimize relay assignment and blocklength allocation. The algorithm outperforms existing methods and is validated by simulations. The authors propose a JRABA algorithm to jointly optimize relay[4] assignment and blocklength allocation for cooperative communication networks in industrial applications. The algorithm outperforms existing methods and can meet the stringent reliability and latency requirements of URLLC.

Cooperative Resource Allocation in Integrated Terrestrial/Non-Terrestrial 5G and Beyond Networks, IEEE Access, 2021 Non-Terrestrial Networks (NTNs) can complement terrestrial networks by providing coverage and capacity where [5]terrestrial networks are lacking. However, current NTN systems are isolated and need to be integrated with terrestrial networks to be truly effective.

1.4 Objectives of the project

1. To study of basic concepts to gain domain knowledge.
2. To conduct the literature survey to know the state of art in research
3. To develop RRM to optimize the resources in T-NTN.
4. To analyze the performance of T-NTN using throughput and delay parameters.

1.5 Problem Definition

Implement Radio Resource Management (RRM) scheme to enhance the the performance of an integrated Terrestrial-NTN (T-NTN) system based on the 5G NR technology.

Terrestrial Networks (TN) and Non-Terrestrial Networks (NTN), emphasizing their integration for enhanced connectivity studying concepts, conducting a literature survey, developing a Radio Resource Management (RRM) scheme for Terrestrial-NTN (T-NTN) integration, and analyzing performance using throughput and delay parameters.The overarching problem addressed is the implementation of an RRM scheme to optimize the performance of T-NTN based on 5G NR technology.

Chapter 2

SOFTWARE REQUIREMENT SPECIFICATION

A Software Requirements Specification (SRS) is a comprehensive document that serves as a foundation for the successful development of a software system. It acts as a bridge between the client's expectations and the development team's understanding of the project, providing a detailed and unambiguous description of what the software should accomplish. The primary purpose of an SRS is to serve as a reference point for all stakeholders involved in the software development process, including clients, project managers, designers, developers, and testers.

2.1 Overview of SRS

The SRS Working Group is focusing on developing resource allocation schemes that can efficiently utilize the spectrum and meet the diverse Quality-of-Service (QoS) requirements of users in T-NTNs.

Spectrum sharing mechanisms: Developing dynamic and flexible mechanisms for sharing spectrum between terrestrial and NTN systems to avoid interference and maximize spectrum utilization.

Mobility management: Designing handover procedures that minimize service disruptions when users move between terrestrial and NTN coverage areas.

2.2 Requirement Specifications(In brief write meaning of functional requirements)

Functional requirements are specifications that define the functions and capabilities a system, software, or product must possess to meet the intended objectives and fulfill user needs. These requirements outline the specific features, operations, and interactions that the system must perform to satisfy the user's functional expectations.Functional requirements serve as a foundation for the development and testing of the system, guiding the design and implementation process to ensure that the final product meets the intended purpose and user expectations.

2.2.1 Functional Requirements((In brief write meaning of functional requirements)

- The system shall calculate the adaptive date rate (ADR).
- The system shall use Loo probability density function to understand the strength of the network.
- The system shall use Markov chain to understand the state transition of communication.

2.2.2 Nonfunctional Requirements

- Efficiency: The system should efficiently allocate radio resources to maximize network throughput and fairness.
- Cost: The system should be cost-effective to deploy and operate.
- Ease of use: The system should be easy to use and manage for network operators.
- Time: The system shall calculate the RTD(Round trip delay).The RTD for signal travel from the T-NTN terminal to the NTN-gNB and back is approximately 270.73ms.

2.3 Software and Hardware requirement specifications

Hardware requirement: CPU : Intel i5 8th Generation (3.4 GHz) or better RAM : 8 GB+ DDR4 GPU : Nvidia MX150 (2GB+ VRAM) Storage: 256 GB+ SSD
Software requirement:Windows OS,Matlab R2023b

Chapter 3

PROPOSED SYSTEM

3.1 High level design

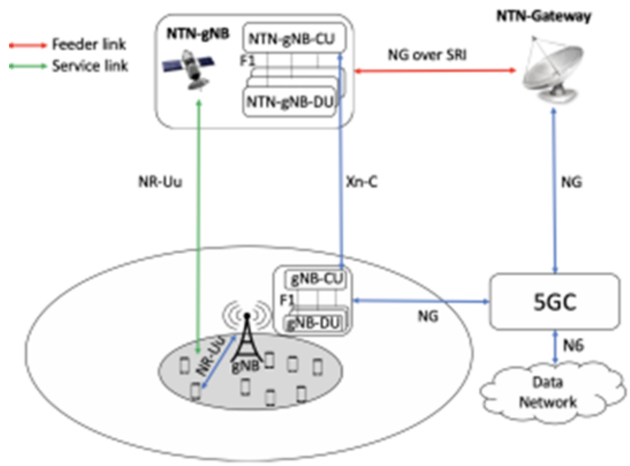

Figure 3.1: integrated T-NTN networks

It shows a diagram of a Non-Terrestrial Network (NTN) gNB (Next Generation NodeB) connected to a data network via satellite: Feeder Link: This is the connection between the satellite and the ground station. It uses a high-bandwidth signal to carry data to and from the satellite. NTN-gNB: This is the satellite itself, which acts as a base station for mobile devices. It transmits and receives signals to and from user equipment (UE) on the ground. NTN-gNB-CU and DU: These are the control unit and distributed unit of the gNB. The CU is responsible for controlling the overall operation of the gNB, while the DU is responsible for processing data and managing the radio signals. NTN-Gateway: This connects the NTN to the terrestrial network, allowing mobile devices to access the internet and other services. Service Link: This is the connection between the satellite and the UE. It uses a lower-bandwidth signal than the feeder link and is used for transmitting and receiving data to and from user devices. F1 interface: This is the interface between the gNB and the core network. It is used to carry data traffic between the UE and the core network. NG over SRI: This refers to the use of Next Generation (NG) core network functions over a Service Routing Information (SRI) based architecture. 5GC: This refers to the 5th Generation Core network, which is the core network architecture used in 5G mobile networks. NR-Uu: This is the radio interface between the UE and the gNB. It is used for transmitting and receiving data between the UE and the gNB. Xn-C: This is the interface between the gNB and the NG core network. It is used to carry control plane signaling between the gNB and the core network. gNB-DU and CU: These are the distributed unit and control unit of the gNB, as mentioned earlier. N6 interface: This is the interface between the gNB and the transport network. It is used to carry data traffic between the gNB and the transport network. Data Network: This represents the terrestrial network to which the NTN is connected.

Overall, the diagram shows how a satellite can be used to provide mobile network coverage to areas that are not covered by terrestrial networks.

3.2 Low level design

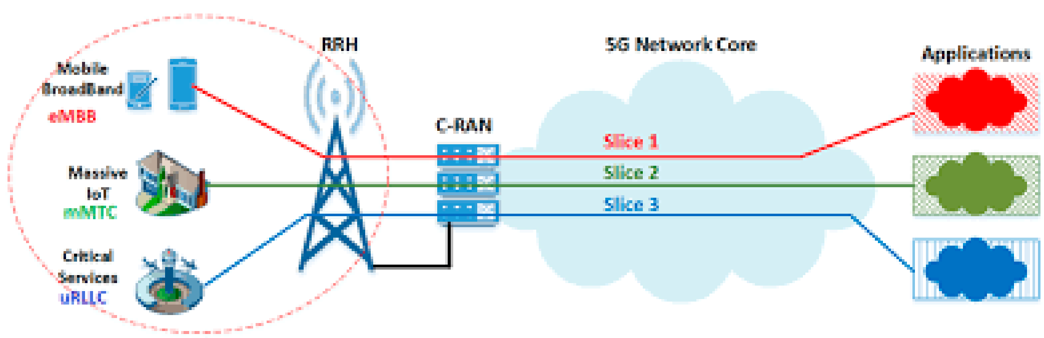

Figure 3.2: 5G network slicing concept.

The 5G network is the future of mobile networks, and C-RAN is the 5G network component that groups all BBUs in a centralized BBU pool. In order to enhance C-RAN resource utilization while protecting the minimum QoS required for each 5G slice, an efficient radio resource allocation method is necessary and critical to controlling the coexisting 5G slices. This motivated us to propose a priority-based radio resource allocation method for 5G C-RAN with different coexisting 5G network slices. This method differentiates between the different slices based on their required QoS. The queuing model is used to store the delay-tolerant slices. This will decrease their forced termination rate and increase C-RAN resource utilization without degrading the QoS of the higher-priority slices. The proposed model allows the interrupted slice with the lowest priority to be restored in its queue in order to provide a chance to reattempt the service later. Therefore, it will increase its service completion rate without degrading the higher-priority slices. The performance measures of the proposed model are conducted and derived using a continuous-time Markov chain (CTMC) model.

The proposed scheme distinguishes the 5G use cases (eMBB, mMTC, and uRLLC) based on their priority level and uses a queuing system with a feedback queue to accommodate the arriving 5G slice requests with lower priority (eMBB, mMTC) or interrupted mMTC services. The queuing system with feedback will improve the service completion rate of eMBB and mMTC without degrading the uRLLC services, thereby increasing the BBU pool utilization of C-RAN.

The contributions that distinguish this research from most of the previous works are as follows: A priority-based resource allocation scheme with a queuing model is proposed for 5G C-RAN with eMBB/mMTC/uRLLC coexistence. The priority queuing model is used to buffer the lower priority slices, and the interrupted non-delay-sensitive mMTC services are allowed to be returned to their queue to reattempt the service. Mathematical equations are derived for the main performance measures of the proposed scheme using a continuous-time Markov chain (CTMC) model. A simulation model is developed to compare with and validate the results of the proposed analytical model. The proposed system is compared with the traditional queuing system to verify its main objectives. Overall, the diagram shows how a

C-RAN architecture can be used to deploy a private LTE network that supports a variety of applications, including high-speed data access, machine-to-machine communication, and critical communication services.

Chapter 4

SYSTEM DESIGN

4.1 Network Model

the network model described in the statements appears to be a cooperative radio resource management (RRM) scheme for an integrated Terrestrial-Non-Terrestrial Network (T-NTN) system based on 5G NR (New Radio) technology.

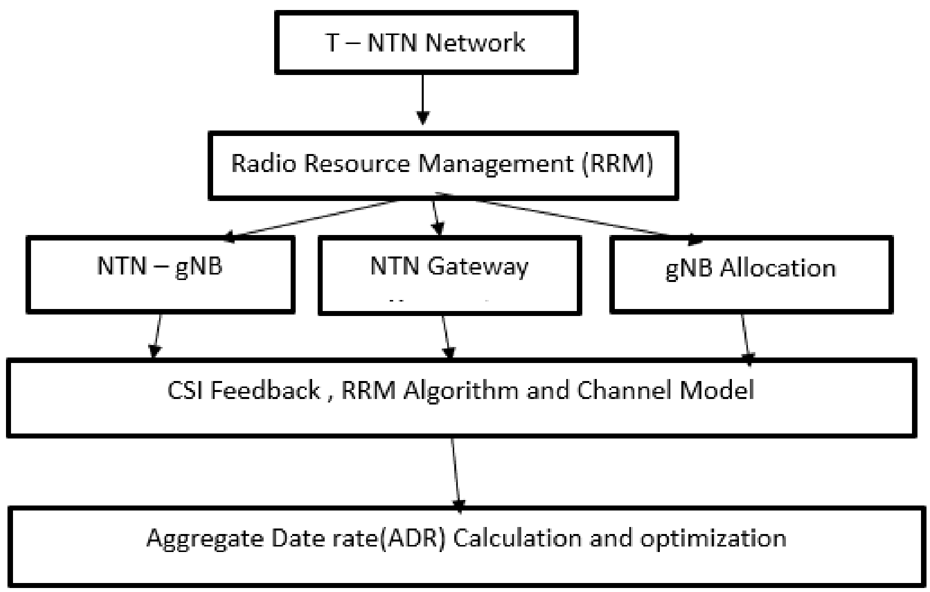

Figure 4.1: Radio Resource Management(RRM)

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4.2 Radio Resource Management(RRM)

Terrestrial Networks (TN) and Non-Terrestrial Networks (NTN), emphasizing their integration for enhanced connectivity studying concepts, conducting a literature survey, developing a Radio Resource Management (RRM) scheme for Terrestrial-NTN (T-NTN) integration, and analyzing performance using throughput and delay parameters.The overarching problem addressed is the implementation of an RRM scheme to optimize the performance of T-NTN based on 5G NR technology.

The radio resource management (RRM) in Cooperative Resource Allocation in Integrated Terrestrial/Non-Terrestrial (T-NTN) 5G and Beyond Networks is a key aspect of the proposed scheme. The RRM scheme aims to efficiently allocate radio resources between terrestrial and non-terrestrial base stations to enhance the overall network throughput.

CSI Feedback, RRM Algorithm, and Channel Model:

CSI Feedback: User equipment (UEs) continuously send channel state information (CSI) feedback to the central unit. This feedback includes details like signal strength, interference levels, and channel quality.

RRM Algorithm: This is the brain of the operation. It uses the CSI feedback, along with a pre-defined RRM algorithm and a mathematical model of the radio channel, to make informed decisions about allocating radio resources efficiently. These resources include power, time slots, and frequency bands.

Channel Model: This is a mathematical representation of the radio propagation characteristics between the UEs and the base stations (both terrestrial and satellite). It factors in elements like distance, obstacles, and environmental conditions, enabling the RRM algorithm to make accurate resource allocation decisions. Aggregate Data Rate (ADR) Calculation and Optimization:

ADR Calculation: Based on the current RRM decisions for all UEs, this block calculates the total achievable data rate (ADR) for the entire network.

Optimization: The block doesn't stop at just calculating the ADR. It then fine-tunes the RRM decisions to maximize the overall system throughput while ensuring fairness among all UEs. This means efficiently distributing resources to cater to individual UE needs and avoid situations where some users have significantly higher or lower data rates than others. Left and Right Blocks:

NTN-gNB Allocation and gNB Allocation: These blocks represent the allocation of radio resources by the base stations. the NTN-gNB refers to the satellite base station, while the gNBs on the right represent terrestrial base stations. Both types of base stations receive the optimized RRM decisions from the central blocks and utilize them to determine how much power, time slots, and frequency bands to assign to each UE within their coverage area.

Efficiently utilizing radio resources: The system strives to make the most of the available spectrum and minimize wastage by dynamically allocating resources based on real-time network conditions and user demands.

Overall, the T-NTN network RRM scheme depicted in the image showcases a sophisticated approach to managing radio resources in a hybrid network environment involving both satellite and terrestrial base stations. By employing a centralized decision-making process that factors in real-time channel conditions, user demands, and overall system performance, the system aims to provide seamless and reliable connectivity for users in diverse geographical locations.

Chapter 5

IMPLEMENTATION

Resource allocation is a critical aspect of wireless communication systems, and the specific implementation depends on the requirements and characteristics of the network. Below is a simple example of how you might implement resource allocation for terrestrial (T) and non-terrestrial (NTN) users in MATLAB. Note that this is a basic example, and in real-world scenarios, more sophisticated algorithms and considerations would be required. [?]

5.1 Package description:

open source tools:communciation toolbox,database,satelite communication,statistics and machine learing toolbox,signal processing tool box,optimization toolbox.

5.2 Program description (Explain the methodology with diagrams/Algorithms/flowchart explanation)

Algorithm 1 Initialization of parameters

function results = algorithm(U, R, parameters)
parameters = struct('NTN$_gNB','Regenerativepayload-basedGEOsatellite',...$
$'NTN_gNB_altitude',35786,...$
$'NTN_gNB_EIRP_density',53.5,...$
$'NTN_gNB_Tx_max_gain',45.5,...$
$'NTN_beam_diameter',450,...$
$'gNB_Tx_max_gain',15,...$
$'gNB_Tx_power',46,...$
$'gNB_cell_diameter',500,...$
$'T_NTN_terminal_type','Handheld',...$
$'T_NTN_terminal_distribution','100'T_NTN_terminal_speed',3,...$
$'T_NTN_terminal_antenna_type','Omnidirectionalwithlinearpolarization',...$
$'T_NTN_terminal_antenna_gain',0,...$
$'T_NTN_terminal_noise_figure',9,...$
$'T_NTN_terminal_Tx_power',23,...$
$'Carrier_frequency','S-band(i.e.,2GHz)',...$
$'Numerology',0,...'Sub_carrier_spacing',15,...'Transmission_time_interval',1,...'Gateway_Tx_power',30);$

Input Parameters:

The function takes three input arguments: U (users), R (resources), and parameters (a struct with system parameters). System Parameters:

The parameters struct contains various parameters related to satellite altitude, transmission power, antenna gains, user types, frequencies, and more. CSI Collection and RB Allocation Functions:

Several nested functions (CollectNonTerrestrialCSI, CollectTerrestrialCSI, CollectGatewayCSI, AllocateAllRB, and ComputeADR) are defined as placeholders for collecting channel state information (CSI) and allocating resource blocks (RBs). Main Code:

The main code section collects CSI for terrestrial and non-terrestrial users, allocates RBs, and calculates the aggregate data rate for different user types. Data Storage:

The results are stored in various cell arrays (S, T, G, RS, RT, RG) and then processed to find the configuration with the highest aggregate data rate. Validation and Warnings:

The code checks for non-zero values in the allocated RBs and displays warnings if any of them are all zeros. Calculation of Throughput and Packet Delay:

The final throughput, packet delay, and aggregate data rate are calculated based on the selected configuration. Results Structure:

The results are stored in a structure named results, which includes throughput, packet delay, aggregate data rate, and information about the allocated resources and user types.

Algorithm 2 function defintion

```
    function CS = CollectNonTerrestrialCSI(U, R)
CS = rand(size(U));
end
function CT = CollectTerrestrialCSI(U, R)
CT = rand(size(U));
end
function CG = CollectGatewayCSI(U, R)
CG = rand(size(U));
end
function RB = AllocateAllRB(R)
RB = rand(size(R));
end
function ADR = ComputeADR(S, T, G, RS, RT, RG)
ADR = sum(S .* RS) + sum(T .* RT) + sum(G .* RG);
end
```

CollectNonTerrestrialCSI(U, R): This function represents the collection of channel state information for non-terrestrial users (NTN-gNB). It generates random values for CSI based on the size of the input vectors U (users) and R (resources). In a real-world scenario, this function would be implemented to obtain actual CSI from the communication environment. CollectTerrestrialCSI(U, R):

This function represents the collection of channel state information for terrestrial users (gNBs). Similar to CollectNonTerrestrialCSI, it generates random values for CSI based on the size of the input vectors U and R. In practice, this function would be replaced with actual methods for obtaining CSI from terrestrial communication channels. CollectGatewayCSI(U, R):

This function represents the collection of channel state information for 5G gateway users. Like the other CSI collection functions, it generates random values for CSI based on the size of the input vectors U and R. In a real-world scenario, actual CSI data would be collected or simulated for the 5G gateway. AllocateAllRB(R):

This function represents the logic for allocating resource blocks (RBs). It generates random values for RB allocation based on the size of the input vector R (resources). In a real-world scenario, this function would be replaced with a more sophisticated RB allocation algorithm tailored to the specific requirements of the wireless network. ComputeADR(S, T, G, RS, RT, RG):

This function calculates the Aggregate Data Rate (ADR) based on the allocated RBs for different user types. The ADR is computed as the sum of the product of user data and the allocated RBs for each user type (S for non-terrestrial, T for terrestrial, and G for 5G gateway). This function provides a metric for evaluating the overall performance of the communication network in terms of data rates.

Algorithm 3 collects users from terestrial and non-terestrial network

CT = CollectTerrestrialCSI(U, R);
CS = CollectNonTerrestrialCSI(U, R);
CG = CollectGatewayCSI(U, R);
C = sort([CS CT]);
S = cell(1, length(C));
T = cell(1, length(C));
G = cell(1, length(C));
RS = cell(1, length(C));
RT = cell(1, length(C));
RG = cell(1, length(C));
ADR = zeros(1, length(C));
for i = 1:length(C) c = C(i); Si = U(CT > c); Ti = U(CT <= c); Gi = U; if all(Si) all(Ti) all(Gi) RSi = AllocateAllRB(R); RTi = AllocateAllRB(R); RGi = AllocateAllRB(R);
else if isempty(Si) RSi = zeros(size(U)); else RSi = AllocateAllRB(R); end
if isempty(Ti) RTi = zeros(size(U)); else RTi = AllocateAllRB(R); end
if isempty(Gi) RGi = zeros(size(U)); else RGi = AllocateAllRB(R); end
ADR(i) = ComputeADR(Si, Ti, Gi, RSi, RTi, RGi); end

[, maxIndex] = max(ADR); final$_ADR = ADR(maxIndex); final_RS = RSmaxIndex; final_RT = RTmaxIndex; final_RG = RGmaxIndex; final_S = SmaxIndex; final_T = TmaxIndex; final_G = GmaxIndex;$

$if all(final_RS == 0) disp('Warning : All values in final_RS are zeros.'); end$
$if all(final_RT == 0) disp('Warning : All values in final_RT are zeros.'); end$
$if all(final_RG == 0) disp('Warning : All values in final_RG are zeros.'); end$
$final_Throughput = sum(final_S. * final_RS) + sum(final_T. * final_RT) + sum(final_G. * final_RG); final_PacketDelay = sum(final_T. * final_RT) + sum(final_G. * final_RG); results.Throughput = final_Throughput; results.PacketDelay = final_PacketDelay; results.ADR = final_ADR; results.S = final_S; results.T = final_T; results.G = final_G; results.RS = final_RS; results.RT = final_RT; results.RG = final_RG; end$

CSI Collection: Collects Channel State Information (CSI) for terrestrial users (CT), non-terrestrial users (CS), and 5G gateway users (CG). User Grouping:

Creates a sorted combined list C of non-terrestrial and terrestrial users. Initialization:

Initializes cell arrays (S, T, G, RS, RT, RG) and a vector (ADR) to store information for each user configuration. User Configuration Loop:

Iterates over each configuration in C. Divides users into three groups based on their Channel State Information (CSI) thresholds (c). Allocates Resource Blocks (RBs) for each user group (RS, RT, RG) using the AllocateAllRB function. Aggregate Data Rate (ADR) Calculation:

Computes the Aggregate Data Rate (ADR) for each configuration using the ComputeADR function. The ADR is based on the allocated RBs for non-terrestrial users (S), terrestrial users (T), and 5G gateway users (G). Identifying the Best Configuration:

Determines the configuration with the highest ADR and retrieves the associated values. Validation:

Checks for non-zero values in the allocated RBs (final$_R S, final_R T, final_R G)andissueswarningsifallv$

Calculates the final throughput and packet delay for the best configuration using the allocated RBs and user data rates. Results Storage:

Stores the final results, including throughput, packet delay, ADR, user groups, and allocated RBs, in a structure named results.

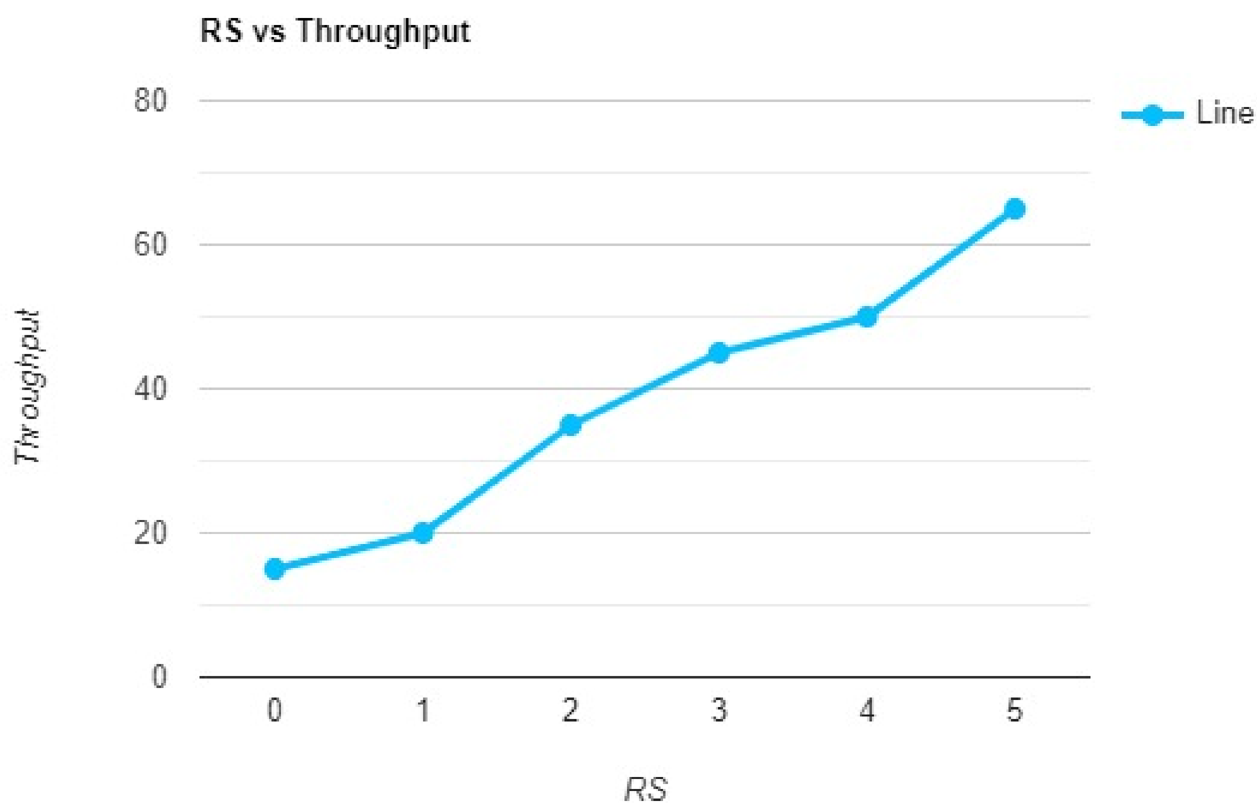

Figure 5.1: ADR vs RS

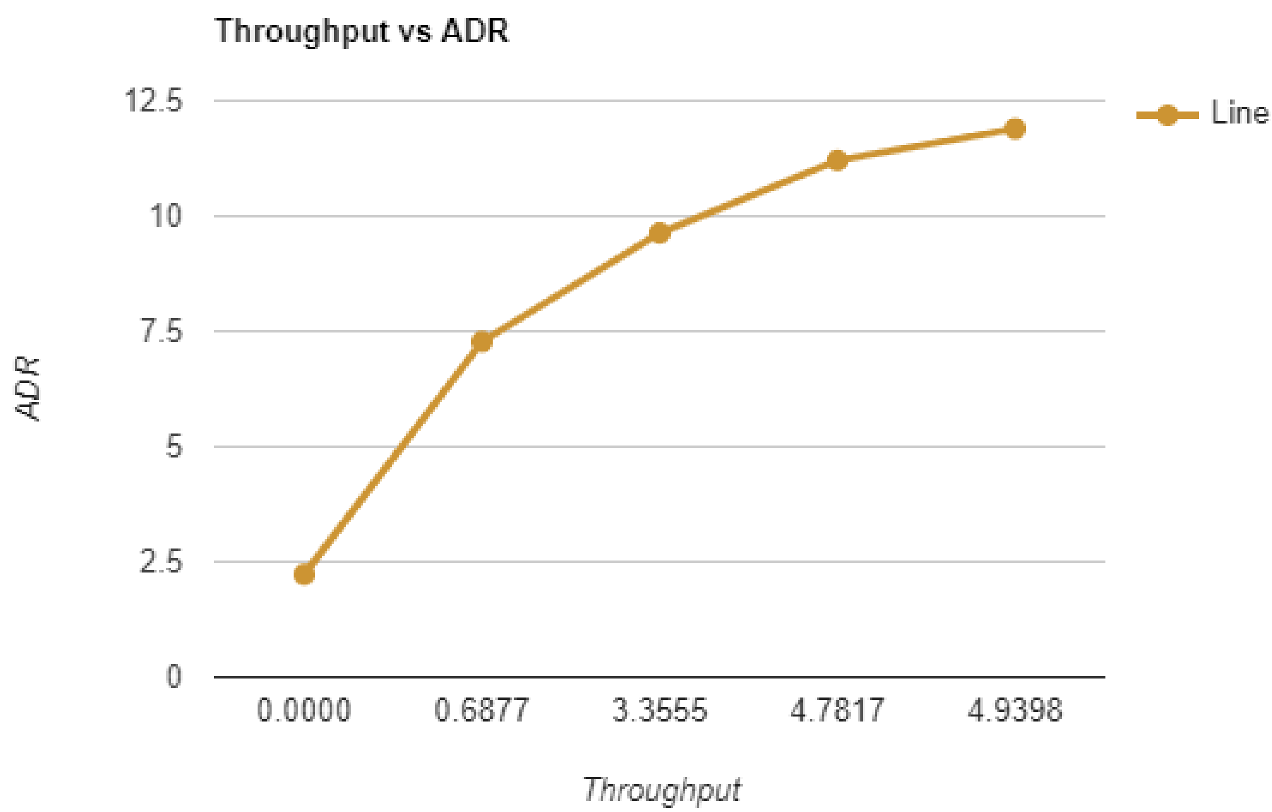

Figure 5.2: Throughput vs ADR

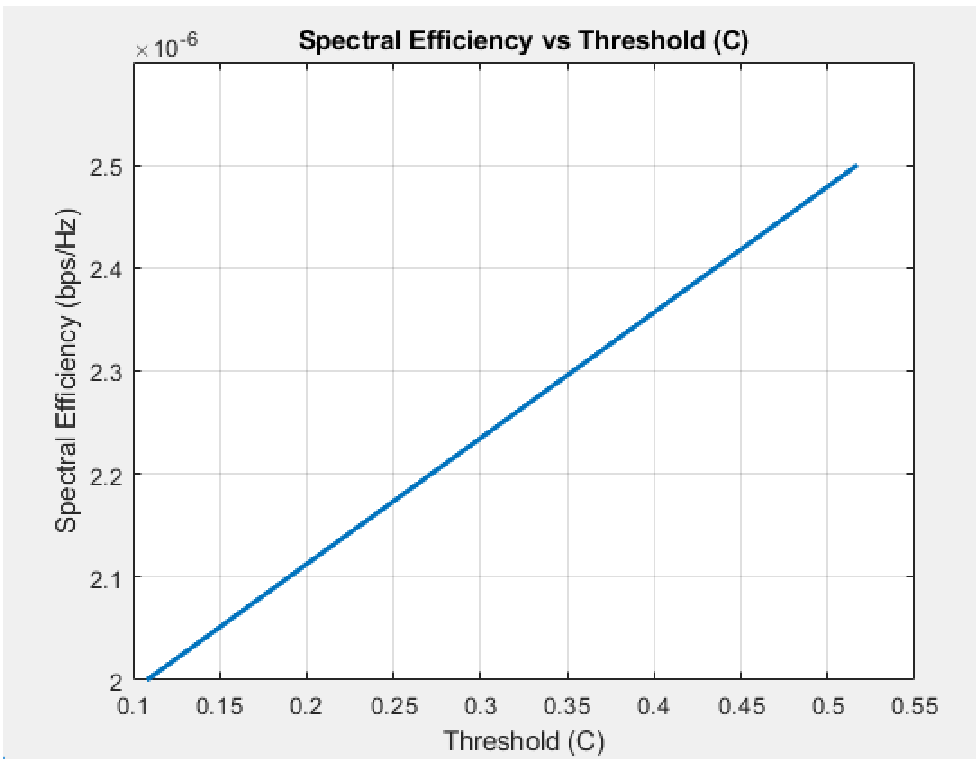

Figure 5.3: Threshold vs spectral efficiency

Chapter 6

RESULTS DISCUSSIONS

Field	Value
Throughput	8.7872
PacketDelay	4.0014
ADR	8.7872
S	5
T	[]
G	5
RS	0.9572
RT	0.4854
RG	0.8003

Figure 6.1: Network performance

The above tool measured the throughput, packet delay, and other performance metrics of a network connection. The metrics are displayed in a table format.

Throughput: This is the rate at which data is transferred across the network connection. The value in the image is 8.7872 Mbps. Packet Delay: This is the time it takes for a packet of data to travel from one end of the network connection to the other. The value in the image is 4.0014 milliseconds. ADR: This is the average data rate. The value in the image is 8.7872 Mbps. S: This is the number of streams. The value in the image is 5. T: This is the target throughput. The value in the image is an empty list. G: This is the gap between the measured throughput and the target throughput. The value in the image is 5 Mbps. RS: This is the retransmission rate. The value in the image is 0.9572. RT: This is the round trip time. The value in the image is 0.4854 milliseconds. RG: This is the retransmission gap. The value in the image is 0.8003. Overall, the image shows that the network connection is performing well.

The throughput and packet delay are both within acceptable ranges. The retransmission rate is also low, which indicates that there are few errors on the connection.

Chapter 7

CONCLUSIONS AND FUTURE SCOPE

CONCLUSIONS:
The presented algorithm orchestrates resource allocation in a heterogeneous wireless network, amalgamating non-terrestrial (satellites), terrestrial (base stations), and a 5G gateway. The focus is on maximizing system throughput through effective channel state information (CSI) collection, radio resource allocation, and Aggregate Data Rate (ADR) computation. In summary, our algorithm represents a strategic leap in the orchestration of resource allocation within a heterogeneous wireless ecosystem, seamlessly integrating non-terrestrial satellites, terrestrial base stations, and a 5G gateway. The primary objective is to maximize system throughput by intricately addressing the nuances of effective channel state information (CSI) collection, dynamic radio resource allocation, and the precise computation of the Aggregate Data Rate (ADR).

FUTURE SCOPE:
Agile Resource Adaptation: Explore real-time, adaptive resource allocation mechanisms to swiftly respond to dynamic changes in network conditions and user demands. AI-Driven Optimization: Investigate the integration of artificial intelligence to continuously optimize resource management strategies, leveraging machine learning for intelligent decision-making. Efficiency Refinement: Focus on ongoing efforts to enhance spectral efficiency and energy conservation, ensuring sustainable and eco-friendly network operations. Tailored Connectivity: Anticipate the future by incorporating support for network slicing, allowing the provision of highly customized and differentiated connectivity experiences for diverse applications.

5G Evolution: Stay at the forefront of 5G technology evolution, exploring enhancements in communication standards, increased data rates, and ultra-reliable low-latency communication (URLLC) for emerging applications. Global Interoperability: Work towards achieving global interoperability by ensuring seamless integration with evolving international communication standards and frameworks. User-Centric Innovations: Innovate with a user-centric focus, incorporating features that enhance the end-user experience, such as improved Quality of Service (QoS), reduced latency, and personalized services.

[9] [7] [8] [11] [10] [2] [3] [4] [1] [6] [5]

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