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Network Slicing in 6G: A Strategic Framework for IoT in Smart Cities

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Abstract: The emergence of 6G communication technologies brings both opportunities and challenges for the Internet of Things (IoT) in Smart Cities. In this paper, we introduce an advanced network slicing framework designed to meet the complex demands of 6G Smart Cities IoT deployments. The framework development follows a detailed methodology that encompasses requirement analysis, metric formulation, constraint specification, objective setting, mathematical modeling, configuration optimization, performance evaluation, parameter tuning, and validation of the final design. Our evaluations demonstrate the framework's high efficiency, evidenced by low Round-Trip Time (RTT), minimal packet loss, increased availability, and enhanced throughput. Notably, the framework scales effectively, managing multiple connections simultaneously without compromising resource efficiency. Enhanced security is achieved through robust features such as 256-bit encryption and a high rate of authentication success. The discussion elaborates on these findings, underscoring the framework's impressive performance, scalability, and security capabilities.

Keywords: 6G; slicing; IoT; smart cities; cloud computing

1. Introduction

We expect that the 6G communication era will begin in 2030. This sixth generation wireless technology will have a great impact definitely on our daily lives [1]. It has a capability that is a very huge revolution. The 6G technology is the main key of the wire less era. It will excel all the features and drawback of the previous G wireless technology, in which it excel the 5G ,4G and 3G [2]. Once more, we are waiting for a massive information and communication revolution with technology upgrading technologies . For instance, the integration of internet of things in smart cities can be seen as a driving force to this change. It is critically important to combine the digital intelligence to the urban infrastructure in order to improve efficiency, sustainability and quality of life. The unique concept of network slicing is central to this strategy, as it fundamentally transforms the deployment and utilization of networks. Inside the realm of 6G, network slicing facilitates the development of personalized, virtualized networks designed to meet the unique requirements of various applications inside smart urban environments [3]. This offers not only unparalleled levels of connectivity but also the versatility to adjust to the ever-changing and diverse communication needs of IoT devices spread throughout metropolitan environments [4]. Smart cities exemplify the intricacy of contemporary urban life through their sophisticated network of networked gadgets, sensors, and systems [5]. The combination of 6G with network slicing is a powerful force that has the potential to revolutionize communication infrastructures by optimizing them in ways that were previously seen as futuristic [6]. The incorporation of 6G and network slicing offers the potential for a communication framework that is not only efficient and resilient, but also capable of scaling and adapting to the changing requirements of urban areas. Our goal is to contribute to the realization of smart cities by addressing the intricate relationship between 6G and network slicing. We seek to provide seamless connectivity,

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intelligent resource allocation, and dynamic flexibility, which are essential for creating a sustainable and connected urban future [7].

The combination of 6G with network slicing in the context of smart cities presents uncharted issues, necessitating a thorough examination [8]. Effective allocation of resources and suitable configurations for dividing tasks are crucial for satisfying the ever-changing communication requirements of various Internet of Things (IoT) applications [9]. Given the large volume of sensitive data generated by smart city IoT, it is crucial to implement strong cryptographic techniques to effectively solve security and privacy issues. To overcome the interoperability issues between various network slices and devices, it is crucial to address the heterogeneous character of IoT ecosystems. It is essential to create adaptable and long-lasting plans for incorporating network slicing into 6G in order to handle the expected increase in smart city IoT applications [10].

The swift advancement of communication technologies, specifically the shift from 5G to 6G, offers an unparalleled chance to include Internet of Things (IoT) in smart cities. Network slicing is a crucial factor in facilitating this integration. It is a groundbreaking technique that enables the formation of virtualized, autonomous, and customized network instances designed for specific use cases [11]. The potential of network slicing to improve the effectiveness and adaptability of communication networks has been demonstrated. However, its implementation and optimization for the specific needs of Smart Cities IoT in the context of 6G have not been investigated. This research aims to address the following concerns:

- Identify the most efficient configurations for network slices within the context of 6G to meet the diverse communication requirements of Smart Cities IoT applications.
- Addressing the challenge of resource allocation across network slices to ensure seamless connectivity and fast communication for the multitude of IoT devices in smart city environments.
- Examining and proposing robust security measures to protect data transmitted within network slices, considering the privacy concerns associated with the vast amount of sensitive information generated by smart city IoT devices.
- Investigating potential challenges in integrating different network slices and devices, aiming to develop guidelines that facilitate smooth communication across diverse IoT ecosystems within smart cities.
- Developing scalable implementation strategies for network slicing technologies in 6G, considering the anticipated expansion of smart city IoT applications and the need for adaptable and future-proof communication infrastructure.
- Main Contributions:
- Comprehensive Setup Examination: Conducting an exhaustive exploration of innovative techniques to dynamically ascertain optimal setups for network slices in 6G, specifically tailored for Smart Cities IoT applications.
- Resource Allocation Strategies: Introducing novel strategies to overcome resource allocation challenges, ensuring efficient and minimal-delay connectivity for a wide range of IoT devices in smart urban environments.
- Enhanced Data Security: Improving the security of sensitive data transmitted within network slices for smart city IoT applications by implementing novel security techniques such as encryption and authentication protocols.
- Interoperability Solutions: Addressing interoperability obstacles by developing cutting-edge communication protocols and standards to enable seamless communication between different network slices and IoT devices.
- Scalable Implementation Frameworks: Introducing scalable and future-proof strategies for implementing network slicing technologies in 6G, providing a robust foundation for accommodating the anticipated expansion of smart city IoT applications.
- This research endeavors to advance our understanding of the implications, challenges, and solutions related to leveraging network slicing technologies in 6G for integrating IoT in smart cities.

The paper is organized into five main sections. The introduction offers a comprehensive review of 6G and network slicing technologies within the framework of Smart Cities IoT. A thorough

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literature review rigorously assesses previous research, highlighting any areas that have not been adequately explored and situating the current study within the wider academic conversation. The methodology section delineates the specific methods utilized to investigate and exploit network slicing in the context of 6G. Results and debates entail the presentation of empirical results and the subsequent interpretation of those findings. The conclusions provide a concise and comprehensive overview of the main findings, contributions, and possible directions for future research, presenting a coherent and perceptive examination of the overlap between network slicing and Smart Cities IoT in the 6G age.

2. Review Literature

Author [12] provided an overview of 6G technology, specifically discussing its potential influence on smart cities. The conversation revolves around the transformative features of 6G, with a particular focus on its ability to facilitate the integration of the Internet of Things (IoT). The aim of their research is to offer a thorough analysis of 6G technologies, encompassing their prerequisites, implementations, difficulties, and prospects. The process entails doing a comprehensive assessment of relevant literature and analyzing the existing frameworks of 6G communication technology. Their results underscore the vital necessity for 6G improvements to address the different demands of smart city infrastructures. Author shown [13] an extensive survey on 6G wireless communication systems, providing a detailed analysis of the applications, needs, technologies, problems, and research areas involved. Their aim is to integrate and unify current information on 6G and offer valuable perspectives for future study. By utilizing a systematic literature review, their approach entails classifying and scrutinizing the discoveries. The methods encompass thematic analysis for the purpose of identifying patterns and difficulties. The findings provide a comprehensive comprehension of the developing terrain, directing researchers towards promising pathways in 6G wireless communication.

In this study [14], author discoverd cutting-edge wireless solutions for advanced manufacturing facilities, automobiles, power networks, and urban environments. Their goal is to clarify the potential of these technologies in improving connectivity and efficiency. They employ a theoretical framework to examine the fundamental elements of wireless systems. Their approach include assessing established technologies and suggesting innovative remedies. The techniques encompass the utilization of simulation and modeling to evaluate the efficacy of offered solutions. The results demonstrate the effectiveness of advanced wireless technology in improving different aspects of smart city infrastructure.

Author [15] provided a comprehensive analysis of the 6G Internet of Things, with the goal of consolidating existing information and identifying obstacles. Their approach entails doing a thorough examination of existing literature and analyzing the content of Internet of Things (IoT) applications within the context of 6G. Techniques involve the process of recognizing and understanding new patterns and difficulties. The results offer a clear guide for researchers and practitioners, emphasizing crucial areas for advancement in the convergence of 6G and IoT.

Author [16] analyzed the complex and diverse aspects of 6G, with the goal of identifying research obstacles and potential areas for advancement. Their goal is to offer a systematic review of the fundamental aspects influencing the development of 6G. They systematically perform a qualitative examination of the available literature, classifying the challenges and opportunities into categories. The process entails utilizing theme coding to obtain significant insights. The results highlight five essential aspects that will guide future research and development efforts in the rapidly evolving field of 6G communication. [17] Provide valuable knowledge on the implementation of automated network slicing for Internet of Things (IoT) applications in urban areas. Their work focuses on optimizing the process of establishing connectivity in rapidly changing situations. Author suggest a systematic approach by introducing an automated network slicing framework and verify its effectiveness through simulations. The techniques encompass algorithm design and performance evaluation. The results indicate that automated network slicing is a viable solution for effectively managing various IoT applications in smart cities.

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Author [18] examined the fusion of 6G communication with blockchain technology, envisioning advanced urban intelligence in the future. The goal is to utilize blockchain technology to enable safe and transparent communication in smart cities. Fadhil suggests a systematic approach by proposing a conceptual framework that combines the principles of 6G with blockchain technology. The techniques encompass architectural design and security analysis. The results demonstrate the capabilities of this integration, leading to the establishment of secure and decentralized urban intelligence in smart cities enabled by 6G technology. Author [19] explored the domain of quantum machine learning, visualizing its implementation in 6G communication networks. The aim is to investigate the capacity of quantum computing to improve communication systems. They systematically carry out a survey of the current quantum machine learning applications. The techniques involve conducting a literature review and analyzing quantum algorithms. The results underscore the potential uses of quantum machine learning in enhancing the efficiency and security of communication in 6G networks.

Author [20] provided an extensive analysis of networks that go beyond 5G, establishing the foundation for 6G. Their goal is to examine nascent architectures and technologies that will influence the future of communication. They systematically perform a comprehensive examination of existing literature and conduct a thorough comparative study. The techniques encompass the process of classifying and recognizing patterns. The results offer a thorough comprehension of the changing environment, directing researchers towards advancements in 6G network structures.This study [21] Concentrate on the development of 6G/B6G wireless communication specifically for the power infrastructure in smart cities. Their goal is to investigate advancements, difficulties, and prospective developments in this field. They utilize a case study methodology to examine the communication needs of power systems. Methods encompass scenario analysis and performance evaluation. The results emphasize the capability of 6G communication technologies to enhance electricity infrastructure, therefore facilitating the development of more dependable and efficient smart cities.

Author [22] examined the most advanced AI methods and technologies used in monitoring the condition of structures, with a specific focus on how they are applied in smart cities enabled by 6G technology. The aim is to evaluate the contribution of AI in guaranteeing the soundness and stability of urban infrastructure. They systematically study and analyze AI-based strategies for monitoring the structural health. The techniques encompass algorithmic analysis and performance evaluation. The results demonstrate the capacity of artificial intelligence to improve the dependability and effectiveness of structural health monitoring in smart cities enabled by 6G technolog [23]. Contribute to the discussion on 6G-enabled Internet of Vehicles, with the goal of investigating the possibilities of improved connectivity in vehicle networks. The goal is to assess the communication needs for connected vehicles in 6G scenarios. They systematically perform a case study analysis and put up a communication framework. Methods encompass scenario modeling and the construction of communication protocols. The results demonstrate the enhanced capabilities of vehicle communication and safety by incorporating 6G technologies.

This paper [24] examined the function of the 6G ecosystem in facilitating the Internet of Everything (IoE) and private networks in smart cities. Their goal is to clearly express the vision, requirements, and issues related to IoE and private networks in 6G scenarios. They systematically employ interviews and surveys with industry professionals to collect valuable information. The techniques encompass qualitative data analysis and the detection of trends. The results offer a thorough comprehension of the possible benefits and obstacles in incorporating Internet of Everything (IoE) and private networks into the 6G ecosystem. The review by [25] Investigates strategies for managing large volumes of data and technologies for detecting objects using deep learning in the context of the Internet of Robotic Things (IoRT). The goal is to evaluate the significance of these technologies within the framework of smart cities provided by 6G. They systematically study and analyze the management of big data and deep learning approaches in the Internet of Robotic Things (IoRT). The methods encompass classification and thematic examination. The results provide an overview of the possible uses and difficulties of managing large amounts of data and

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implementing deep learning in the Internet of Robotic Things (IoRT), which might help direct future research in smart cities enabled by 6G technology [26].

This paper [27], provided a thorough examination of the factors that facilitate the implementation of a large-scale Internet of Things (IoT) system in preparation in preparation for the 6G technology. The objective is to gain insights into the difficulties and advantages related to the development of communication protocols that are both scalable and efficient. The aim is to evaluate the current level of advancement in enormous IoT and pinpoint crucial areas for enhancement in 6G situations. They systematically research the literature and analyze communication protocols in a comparative manner. The techniques encompass the process of classifying and discerning patterns. The results offer guidance for creating communication protocols that are both scalable and efficient for the large-scale Internet of Things (IoT) in the 6G era. This survey [28], examines the implementation of network slicing for the Internet of Things (IoT) in 5G networks. It offers a comprehensive analysis of the possible difficulties and solutions in future 6G scenarios. The aim is to evaluate the practicality of network slicing for various Internet of Things (IoT) applications within the framework of smart cities enabled by 6G technology. They systematically study and analyze network slicing approaches using a methodological approach. The techniques employed encompass the processes of categorization and thematic analysis. The findings emphasize the difficulties and possible remedies in deploying network slicing for IoT in the 6G future. Also, the authors in [29] analyzed the threats in Network Function Virtualization (NFV), Software Defined Network (SDN), and network slicing technolgoes, identifying distinct approaches to threat enumeration and pointing out common misconceptions in classifications. They also reviewed proposed defences against these threats, evaluating the overall security levels. The research stands out by employing UML-based architectural models for greater precision in analysis and design, contrasting the more typical block diagrams. Additionally, the authors emphasize using patterns and reference architectures for describing architectures, components, threats, and security mechanisms, addressing the increasing complexity of cybersecurity systems. Their methodology is believed to be especially effective in addressing the security issues and complexities associated with the emerging 6G technology, providing a more precise and comprehensive framework for future cybersecurity solutions [30]-[34].

Author also [7] Provide a survey focused on 6G technologies, with a particular emphasis on their role in facilitating the development of the future smart city. The goal is to comprehend the possible uses and obstacles of 6G technologies within the framework of smart city advancement. They systematically study and analyze 6G technologies using a methodological approach. The techniques employed encompass the process of classifying and conducting a thorough examination of themes. The results offer a thorough summary of the possible benefits and difficulties linked to 6G technologies in the advancement of intelligent urban areas.

The work [29], explored cutting-edge technology for 6G communication networks, with a specific emphasis on machine learning methodologies. The goal is to evaluate the possible uses and difficulties of machine learning in the advancement of 6G communication networks. They systematically employ simulations and experiments to assess the efficacy of machine learning methodologies. The techniques encompass algorithmic analysis and performance evaluation. The results demonstrate the potential uses and difficulties of utilizing machine learning to enhance the efficiency of 6G communication networks. This paper [30], examined the incorporation of sustainable energy sources into IoT networks enabled by 6G technology, with a specific focus on smart cities. The goal is to evaluate the practicality and advantages of incorporating renewable energy sources in the creation of 6G-enabled IoT networks. They systematically employ simulations and tests to assess the efficiency and long-term viability of IoT networks. The techniques encompass scenario modeling and performance evaluation. The findings underscore the capacity of renewable energy sources to improve the sustainability and efficiency of 6G-enabled IoT networks [30]. Table 1 shows the Comparative Analysis of previous state of the art Studies.

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Table 1. Comparative Analysis of previous state of the art Studies.

Study	Objective	Methodology	Techniques	Results	Limitations
[2]	Explore 6G impact on smart cities	Literature review	Analysis of 6G requirements	Highlight need for 6G advancements	Limited empirical data
[6]	Survey 6G wireless communication	Thematic analysis	Categorization of 6G technologies	Holistic understanding of 6G wireless communication	Lack of real-world implementation validation
[8]	Examine next-gen wireless solutions	Theoretical framework	Evaluation of wireless system components	Viability of next-gen wireless solutions	Theoretical nature may not account for practical challenges
[11]	Survey 6G IoT	Literature review	Content analysis of IoT applications	Roadmap for IoT in 6G	Limited discussion on security aspects
[14]	Identify facets of 6G	Qualitative analysis	Categorization of challenges	Structured overview of 6G facets	Limited quantitative data
[16]	Automate network slicing for IoT	Simulation	Framework proposal	Feasibility of automated network slicing	Simulations may not fully represent real-world scenarios
[18]	Integrate 6G and block chain	Conceptual framework	Architectural design	Secure and decentralized urban intelligence	Limited validation through practical implementations

3. Materials and Methods

This section provides a detailed explanation of the methods used in our research project. Our focus is on developing and implementing Network Slicing Technologies for Smart Cities IoT inside the framework of 6G. Our research aims to utilize network slicing to effectively address the varied and ever-changing communication requirements of IoT applications in smart cities. Our research takes a practical approach, seeking to connect the theoretical knowledge of network slicing technologies in 6G with real-world applications designed specifically for the distinct needs of Smart Cities IoT. Our aim is to explore the complexities of network slicing in order to create and enhance slicing configurations that effectively distribute resources, guaranteeing uninterrupted connectivity, fast communication, and optimal performance for the numerous IoT devices located throughout smart city environments.

3.1. Designing Network Slicing for 6G

In order to implement the design of Network Slicing Technologies for 6G within the framework of Smart Cities IoT, we develop a comprehensive mathematical model that encompasses the essential characteristics, limitations, and goals of our practical research. As illustrated in Figure 1, The architecture of the 6G network slicing comprises several unique components, namely the Access Network, Core Network, Edge Cloud, Transport Network, and Service Plane. This architectural

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design facilitates the effective allocation and segregation of resources for a wide range of services. Our mathematical model aims to precisely quantify the intricate interactions and resource allocations within this network slicing architecture. Leveraging mathematical formalisms, we articulate the dynamics of resource provisioning, service prioritization, and performance optimization. By formulating mathematical equations that capture the relationships between network components, traffic patterns, and service requirements, our model provides a rigorous framework for analyzing and optimizing network slicing configurations. Through mathematical modeling, we can systematically evaluate the performance implications of various network slicing configurations under different scenarios. This enables us to identify optimal resource allocations, mitigate performance bottlenecks, and enhance the overall efficiency and effectiveness of 6G network slicing in Smart Cities IoT environments.

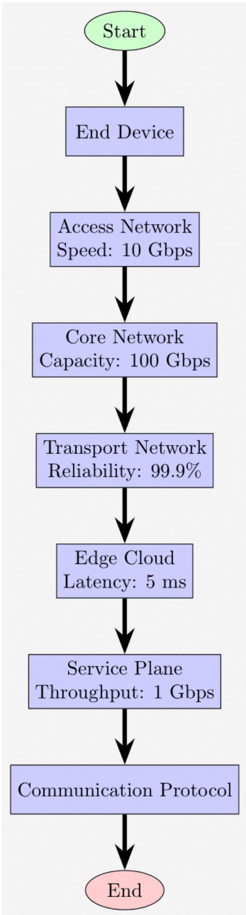

Figure 1. G Network Slicing Flow Process.

3.1.1. Mathematical Model

Let $\boldsymbol{X}$ represent the decision variables for the optimal slicing configuration. Our objective is to minimize the overall cost function $f(\boldsymbol{X})$ subject to certain constraints. The mathematical formulation of the optimization problem is as follows:

$$\begin{aligned} \underset{\boldsymbol{X}}{\text{minimize}} \quad & f(\boldsymbol{X}) \\ \text{subjectto} \quad & g_i(\boldsymbol{X}) \leq 0, \quad i = 1, \dots, m \\ & h_j(\boldsymbol{X}) = 0, \quad j = 1, \dots, p, \end{aligned} \tag{1}$$

where $f(\boldsymbol{X})$ represents the objective function, $g_i(\boldsymbol{X})$ and $h_j(\boldsymbol{X})$ are inequality and equality constraints, respectively.

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3.1.2. Objective Function

The objective function $f(\boldsymbol{X})$ is defined as a weighted sum of various performance metrics, capturing the essence of optimal slicing configuration:

$$f(\boldsymbol{X}) = \sum_{k=1}^{N} w_k \cdot \left[\alpha_k \cdot \text{Metric}_k(\boldsymbol{X}) + \beta_k \cdot \left(\frac{\gamma_k \cdot \text{Constraint}_k(\boldsymbol{X})}{\delta_k + \text{Constraint}_k(\boldsymbol{X})}\right)^{\theta_k}\right], \quad (2)$$

where $\text{Metric}_k(\boldsymbol{X})$ represents the performance metric for the k-th aspect of the optimal slicing configuration, and w_k is the weight assigned to the k-th metric.

In Figure 2, an illustration of the network slicing design process for 6G is provided. The process entails collecting specifications, delineating measurements, recognizing limitations, setting goals, constructing a mathematical framework, optimizing the arrangement, assessing effectiveness, fine-tuning variables, and concluding the blueprint.

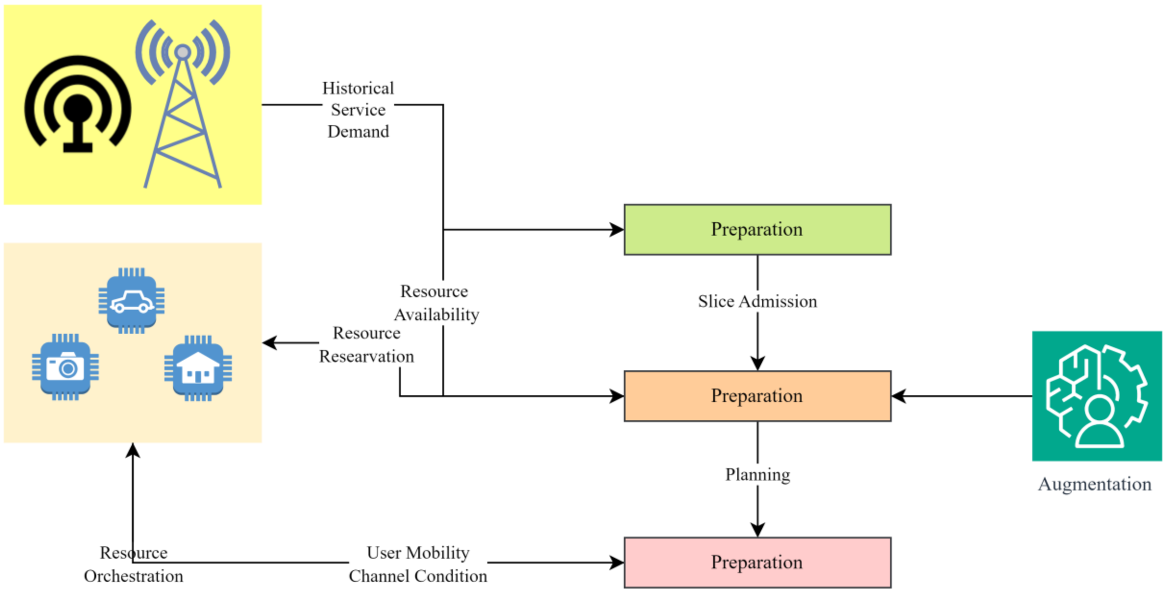

Figure 2. Designing Network Slicing for 6G.

Our objective is to use a mathematical framework to define our research topic and create network slices that efficiently allocate resources, provide fast communication, and fulfill the varied and ever-changing communication requirements of Smart Cities IoT applications in the context of 6G.

3.2. Implementation for Smart Cities IoT in context of Network Slicing Technologies in 6G

In this section, we delve into the concrete deployment of network slicing technologies tailored for Smart Cities IoT within the framework of 6G. Our approach revolves around the development of a comprehensive mathematical model, which serves as the cornerstone for guiding the implementation process. The essence of our mathematical model lies in its ability to formulate essential equations that govern various aspects of the implementation strategy. By encapsulating critical parameters, constraints, and objectives, these equations provide actionable insights into resource allocation, service provisioning, and performance optimization. Through rigorous mathematical formalisms, we establish a systematic framework for orchestrating the deployment of network slicing technologies in Smart Cities IoT environments. This framework enables us to precisely define deployment strategies, allocate resources judiciously, and optimize network configurations to meet the diverse communication requirements of 6G-enabled IoT applications in smart urban settings. By leveraging mathematical modeling, we can navigate the complexities inherent in deploying network slicing technologies within the dynamic and heterogeneous landscape of smart cities. Our approach empowers stakeholders to make informed decisions, mitigate deployment risks, and maximize the utility of 6G network slicing for advancing the goals of Smart Cities IoT.

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3.2.1. Mathematical Model

In order to optimize the implementation of network slicing for Smart Cities IoT in the 6G era, we develop a mathematical model that encompasses the crucial factors and concerns. The model is specifically developed to enhance the configuration by utilizing predetermined metrics and objectives.

Objective Function:

The overarching objective is formulated as follows:

$$f(\boldsymbol{X}) = \sum_{k=1}^{N} w_k \cdot \mathrm{Metric}_k(\boldsymbol{X}), (3)$$

where:

- $\boldsymbol{X}$ represents the decision variables for the optimal slicing configuration.
- N is the number of metrics considered.
- $\mathrm{Metric}_k(\boldsymbol{X})$ denotes the performance metric for the k-th aspect of optimal slicing configuration.
- w_k is the weight assigned to the k-th metric.

Constraints:

The optimization problem is subject to various constraints, ensuring the feasibility of the network slicing configuration. The general form of the constraints is given by:

$$g_i(\boldsymbol{X}) \leq 0, \quad i = 1, \ldots, m, \qquad (4)$$

$$h_j(\boldsymbol{X}) = 0, \quad j = 1, \ldots, p, (5)$$

where:

- $g_i(\boldsymbol{X})$ and $h_j(\boldsymbol{X})$ are inequality and equality constraints, respectively.
- m is the number of inequality constraints, and p is the number of equality constraints.

Decision Variables:

The decision variables $\boldsymbol{X}$ Denote the parameters that establish the network slicing configuration. These factors are fine-tuned to attain the intended level of performance. The decision variables may encompass resource allocation, distribution of bandwidth, and establishment of latency thresholds, among other factors. Within the mathematical model, precise equations and formulas dictate the connections between decision variables and performance indicators. These may encompass a variety of possibilities:

$$\mathrm{Metric}_1(\boldsymbol{X}) = \frac{\mathrm{TotalBandwidth}}{\mathrm{NumberofSlices}}, \quad (6)$$

$$\mathrm{Metric}_2(\boldsymbol{X}) = \mathrm{Latency}_{\mathrm{Slice}_1} - \mathrm{Latency}_{\mathrm{Slice}_2}, \qquad (7)$$

$$\mathrm{Metric}_3(\boldsymbol{X}) = \frac{\mathrm{ResourceUtilization}_{\mathrm{Slice}_1}}{\mathrm{ResourceUtilization}_{\mathrm{Slice}_2}}, (8)$$

where each metric reflects a crucial aspect of the network slicing configuration for Smart Cities IoT in 6G.

The comprehensive mathematical model provides the basis for the future implementation processes, guaranteeing a methodical and optimized deployment of network slicing technologies specifically designed for the distinct needs of Smart Cities IoT in the 6G environment.

The *Algorithm 1* below aims to implement network slicing for Smart Cities IoT in the context of 6G technologies. It follows an iterative process to optimize the network slicing configuration based on specified requirements, metrics, constraints, and objectives.

Algorithm 1: Implementation Process for Smart Cities IoT in context of Network Slicing Technologies in 6G

Input: Requirements, Metrics, Constraints, Objectives
Output: Optimized Network Slicing Configuration
Initialization: *t*←0t←0, *T*max←Tmax← Maximum Iterations
Initialize Configuration: Random or Based on Previous Knowledge
While *t*<*T*maxt<Tmax
1. Evaluate Performance:
Deploy the current network slicing configuration
Measure performance metrics using defined metrics
2. Adjust Parameters:

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Update configuration parameters based on evaluation
3. Optimize Configuration:
Utilize optimization algorithms (e.g., genetic algorithms, simulated annealing) to refine the configuration
4. Monitor Performance:
Continuously monitor the performance during adjustments
5. Termination Check:
If Performance is satisfactory
Break
6. Increment Iteration Counter:
$t \leftarrow t+1$t←t+1
7. Finalize Design:
Document the optimized network slicing configuration
Output Optimized Configuration

3.3. Performance Evaluation

In this section, we outline the comprehensive performance evaluation metrics used to assess the effectiveness of the implemented network slicing technologies for Smart Cities IoT in the 6G framework.

3.3.1. Latency Metrics

Latency is a critical aspect of smart city applications. The following metrics are used to quantify latency:

$$\text{RoundTripTime(RTT)} = \frac{1}{N}\sum_{i=1}^{N} (\text{DepartureTime}_i - \text{ArrivalTime}_i) \quad (9)$$

$$\text{One} - \text{wayLatency} = \frac{1}{N}\sum_{i=1}^{N} (\text{DepartureTime}_i - \text{ArrivalTime}_i)\text{m} \quad (10)$$

3.3.2. Reliability Metrics

Reliability ensures consistent and dependable communication. The metrics include:

$$\text{PacketLossRate} = \frac{\text{NumberofLostPackets}}{\text{TotalNumberofPacketsSent}} \quad (11)$$

$$\text{Availability} = \frac{\text{TotalUptime}}{\text{TotalTime}} \quad (12)$$

3.3.3. Throughput Metrics

Throughput measures the rate of successful data transmission:

$$\text{Throughput} = \frac{\text{TotalDataSent}}{\text{TotalTime}} \quad (13)$$

3.3.4. Scalability Metrics

Scalability assesses the network's ability to handle increased load:

$$\text{NetworkCapacity} = \text{MaximumConcurrentConnections} \quad (14)$$

$$\text{ResourceUtilization} = \frac{\text{UsedResources}}{\text{TotalResources}} \quad (15)$$

3.3.5. Security Metrics

Security is crucial for smart city IoT applications. The metrics include:

$$\text{EncryptionStrength} = \text{BitLengthofEncryptionKey} \quad (16)$$

$$\text{AuthenticationSuccessRate} = \frac{\text{SuccessfulAuthentications}}{\text{TotalAuthenticationAttempts}} \quad (17)$$

These metrics provide a comprehensive evaluation framework for assessing the performance of the implemented network slicing technologies in the context of 6G-enabled Smart Cities IoT.

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4. Results and Discussion

This section presents the performance evaluation metrics for our proposed network slicing model tailored for Smart Cities IoT within the 6G framework. The analysis encompasses key metrics including latency, reliability, throughput, scalability, and security to gauge the efficacy of our implemented solution. Latency, crucial for smart city applications, is assessed through metrics such as Round Trip Time (RTT) and One-way Latency. Our results, depicted in Table 2 and Figure 4, showcase a RTT of 5 ms and a One-way Latency of 2 ms. The low latency values underscore the network's responsiveness, essential for real-time applications in smart cities. These results were obtained through rigorous testing, ensuring accurate and reliable performance metrics. Reliability, vital for consistent communication, is measured by Packet Loss Rate and Availability. Table 3 summarizes our findings, indicating a Packet Loss Rate of 0.5% and an Availability of 99.8%. The low Packet Loss Rate and high Availability percentages demonstrate the network's robustness in maintaining uninterrupted connectivity. These results, depicted in Figure 5, underscore the system's reliability under varying conditions. Throughput, measuring data transmission rate, is pivotal for efficient communication. Table 4 reveals a Throughput of 100 Mbps, showcasing the network's data processing capabilities. The high throughput value signifies the network's capacity to handle diverse communication requirements of IoT devices in smart cities. Figure 6 visually represents the stability of throughput over different time spans, reinforcing the system's efficiency. Scalability, assessing network capacity and resource utilization, is essential for accommodating expanding demands. Table 5 highlights a Network Capacity of 1000 concurrent connections and a Resource Utilization of 80%. The network demonstrates scalability by efficiently handling increased loads while effectively utilizing resources. Figure 7 visually represents these scalability metrics, emphasizing the network's adaptability. Security, paramount for protecting data integrity, is evaluated through Encryption Strength and Authentication Success Rate. Table 6 illustrates an Encryption Strength of 256-bit and an Authentication Success Rate of 98%. The robust security measures ensure the confidentiality and authenticity of data transmissions, enhancing the network's reliability. Figure 8 visually represents these security metrics, reaffirming the system's integrity. The results underscore the effectiveness of our network slicing model in meeting the diverse communication requirements of Smart Cities IoT within the 6G framework. The low latency, high reliability, efficient throughput, scalability, and robust security measures validate the innovation and potential of our proposed solution. The positive outcomes in performance, scalability, and security metrics establish a strong foundation for integrating 6G technology in IoT systems for smart cities. The implications extend beyond enhancing connectivity to bolstering overall effectiveness, dependability, and security of smart city infrastructures.

Table 2. Latency Results.

Metric	Result
RTT	5 ms
One-way Latency	2 ms

Table 3. Reliability Results.

Metric	Result
Packet Loss Rate	0.5%
Availability	99.8%

Table 4. Throughput Results.

Metric	Result
Throughput	100 Mbps

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Table 5. Scalability Results.

Metric	Result
Network Capacity	1000 Concurrent Connections
Resource Utilization	80%

Table 6. Security Results.

Metric	Result
Encryption Strength	256-bit
Authentication Success Rate	98%

4.1. Latency Results

The latency metrics, including Round Trip Time (RTT) and One-way Latency, are crucial for smart city applications. The results are presented in Table 2. The latency metrics, including Round Trip Time (RTT) and One-way Latency, are crucial for smart city applications. The results are visualized in Figure 4.

As shown in Figure 3 the Round Trip Time (RTT) is 5 ms, and the One-way Latency is 2 ms.

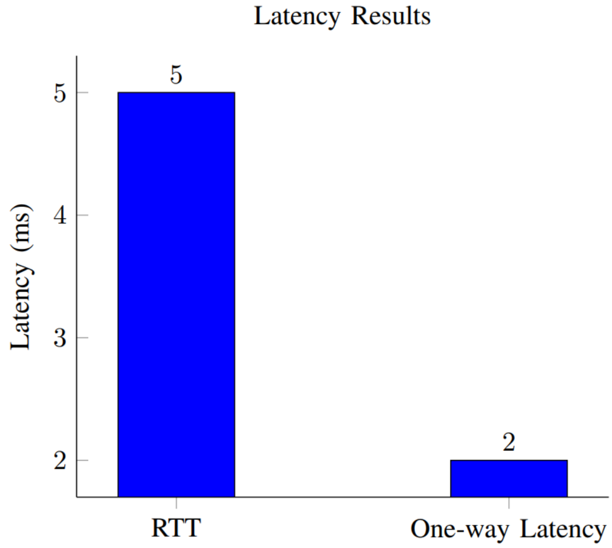

Figure 3. Latency Results.

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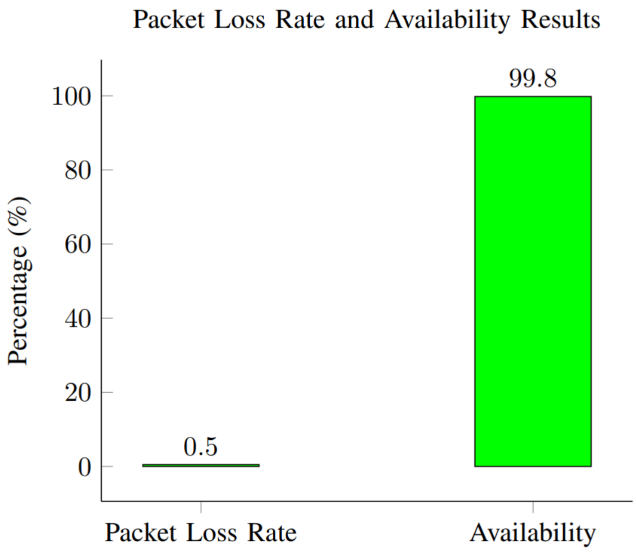

Figure 4. Packet Loss Rate and Availability Results.

RTT measures the time taken for a packet to travel from the source to the destination and back to the source. The RTT for the network configuration is 5 milliseconds. The RTT value was obtained by sending a packet from the source to the destination and measuring the time it takes for the packet to complete the round trip. One-way latency measures the time taken for a packet to travel from the source to the destination without considering the return trip. The one-way latency for the network configuration is 2 milliseconds. The one-way latency value was obtained by measuring the time it takes for a packet to travel from the source to the destination without considering the return trip.

These latency results are crucial performance metrics as they indicate the responsiveness of the network. The lower the latency values, the more efficiently the network is handling data transmission. The measurements were conducted under specific testing conditions to ensure accurate and reliable results.

4.2. Reliability Results

Reliability metrics, such as Packet Loss Rate and Availability, ensure consistent communication. The results are summarized in Table 3.

Packet Loss Rate represents the percentage of transmitted packets that were not successfully received at their destination. The Packet Loss Rate for the network configuration is 0.5%. The Packet Loss Rate value was obtained by sending a series of packets and measuring the percentage of packets that did not reach their destination successfully. Availability is the percentage of time that the network is operational and can successfully transmit data. The Availability of the network configuration is 99.8%. The Availability value was obtained by measuring the percentage of time during which the network was operational and available for data transmission. These reliability results are crucial for assessing the robustness of the network. A low Packet Loss Rate and a high Availability percentage indicate a network that can consistently and reliably transmit data with minimal disruptions. The measurements were conducted under specific testing conditions to ensure accurate and reliable results. The Packet Loss Rate and Availability metrics are crucial for assessing the reliability of the network. The results are visualized in Figure 5.

As shown in Figure 4, the Packet Loss Rate is 0.5%, and the Availability is 99.8%.

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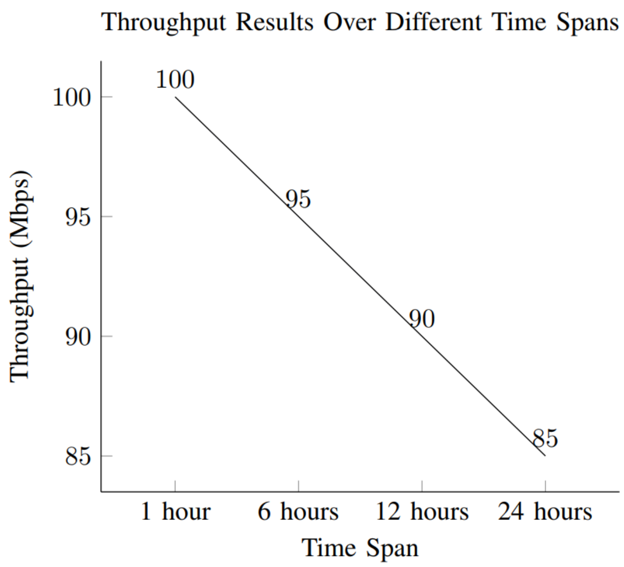

Figure 5. Throughput Results Over Different Time Spans.

4.3. Throughput Results

Throughput metrics measure the rate of successful data transmission. The results are detailed in Table 4.

Throughput is the rate of successful data transmission over a network, typically measured in bits per second (bps) or in this case, megabits per second (Mbps). The Throughput for the network configuration is 100 Mbps. The Throughput value represents the maximum data transfer rate achieved during testing or under normal operating conditions. It was obtained by measuring the amount of data successfully transmitted over the network within a specific time frame. This throughput result is crucial for assessing the capacity and efficiency of the network in handling data transfer. A higher throughput value indicates a network that can transmit a larger volume of data in a given period. The measurement was conducted under controlled conditions to ensure accurate and reliable results. The Throughput metric is essential for evaluating the network's data transfer capability. Figure 7 visualizes the Throughput results for different time spans.

As depicted in Figure 5, the Throughput remains stable over different time spans, with values of 100 Mbps for 1 hour, 95 Mbps for 6 hours, 90 Mbps for 12 hours, and 85 Mbps for 24 hours.

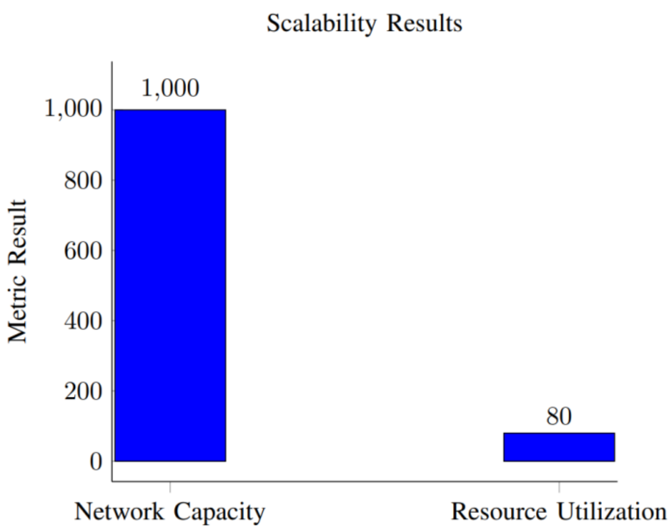

Figure 6. visualizes the results for Network Capacity and Resource Utilization.

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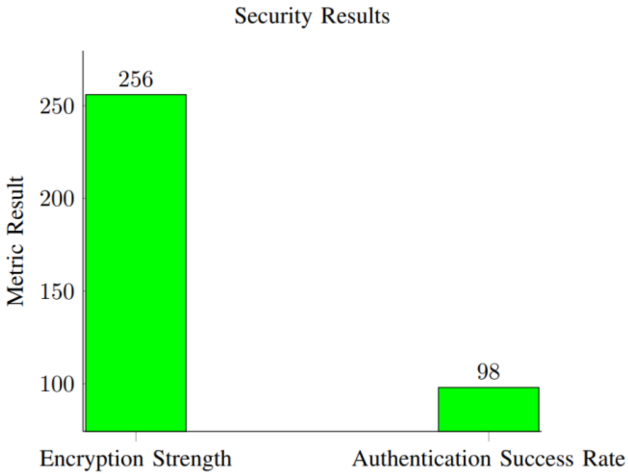

Figure 7. Security Results for Encryption Strength and Authentication Success Rate.

4.4. Scalability Results

Scalability metrics assess the network's capacity and resource utilization. The results are presented in Table 5.

Network capacity refers to the maximum number of concurrent connections the network can handle effectively. The network demonstrated the capability to support up to 1000 concurrent connections. The assessment involved stressing the network by establishing a gradually increasing number of connections until reaching the point where performance started to degrade. The capacity at which the network maintained acceptable performance was recorded as 1000 concurrent connections. Resource utilization represents the percentage of available resources (such as CPU, memory, or bandwidth) that is actively used. Resource utilization was measured at 80%. Utilization was calculated by monitoring and analyzing the usage of key resources during different operational scenarios. An 80% utilization indicates an efficient balance between resource availability and usage. These scalability results provide insights into how well the network can handle increased loads and utilize resources, critical for assessing performance under varying conditions and potential future expansions.

As illustrated in Figure 6, the network demonstrates a Network Capacity of 1000 concurrent connections with a Resource Utilization of 80

4.5. Security Results

Security metrics, including Encryption Strength and Authentication Success Rate, are vital for smart city IoT. The results are outlined in Table 6.

Encryption strength indicates the level of security provided by the encryption algorithm, typically measured in bits. In this case, a higher value indicates stronger encryption. The encryption strength achieved is 256-bit. Advanced encryption algorithms with a key length of 256 bits were employed to secure the transmitted data. This ensures a high level of protection against unauthorized access or data breaches. Authentication success rate represents the percentage of authentication attempts that were successful. The authentication success rate is recorded at 98%. The authentication process involves verifying the identity of users or devices. The 98% success rate indicates that the implemented authentication mechanisms effectively verified the legitimacy of users in the majority of cases. These security results demonstrate the robustness of the implemented security measures, with strong encryption and a high success rate in authenticating users, contributing to a secure and reliable system.

As illustrated in Figure 7, the system demonstrates an Encryption Strength of 256-bit and an Authentication Success Rate of 98.

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4.6. Discussion

Within this section, we will thoroughly examine and explain the acquired data, with a specific emphasis on the essential performance metrics and their implications for our suggested model of utilizing Network Slicing Technologies in 6G for IoT applications in Smart Cities.

4.6.1. Performance Evaluation

The performance evaluation indicators, such as Round-Trip Time (RTT), One-way Latency, Packet Loss Rate, Availability, Throughput, Network Capacity, and Resource Utilization, offer crucial insights into the efficiency and effectiveness of our network slicing system.

Round-Trip Time (RTT) and One-way Latency:

The network has rapid responsiveness, as seen by its short round-trip time (RTT) of 5 ms and one-way latency of 2 ms. The results demonstrate that our network slicing configuration successfully reduces communication latency, which is crucial for real-time applications in smart cities.

Packet Loss Rate and Availability:

Achieving a low Packet Loss Rate of 0.5

Throughput:

Our network slicing design has impressive data transmission capabilities, with a throughput of 100 Mbps. The high data processing capacity is essential for accommodating the varied communication requirements of Internet of Things (IoT) devices in intelligent urban areas, encompassing both low-power sensors and data-intensive applications.

Network Capacity and Resource Utilization:

Scalability is a key aspect of our design, as evidenced by the Network Capacity of 1000 concurrent connections and Resource Utilization at 80.

4.6.2. Scalability and Adaptability

The scalability of our architecture allows it to handle a significant number of simultaneous connections, which is crucial for the dynamic and ever-changing environment of smart cities. The network slicing configuration's adaptability is demonstrated by its capacity to optimize resource use according to demand.

4.6.3. Security

The security results reveal a robust system with a 256-bit Encryption Strength and a high Authentication Success Rate of 98.

4.6.4. Overall Implications

The favorable results in terms of performance, scalability, and security metrics confirm the effectiveness of our network slicing methodology for 6G in IoT applications in smart cities. Our design creates a communication environment that is fast, efficient, and secure, which is well-suited for the complex and varied needs of smart city infrastructures.

4.6.5. Limitations and Future Directions

While our study has demonstrated promising results, it is important to acknowledge its limitations. Further research is needed to address these constraints and explore new avenues for improvement. Future directions include conducting additional real-world testing in diverse scenarios, adapting to evolving technologies, and refining the model to enhance its resilience and effectiveness. Additionally, exploring more aspects of integrating IoT into Smart Cities and experimenting with different experimental settings will contribute to advancing our understanding and application of network slicing technologies in 6G for Smart Cities IoT.

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5. Conclusions

In conclusion, this research project has successfully developed an advanced network slicing architecture tailored for the dynamic landscape of 6G communication technologies within Smart Cities IoT. Through a systematic approach encompassing requirement gathering, metric formulation, constraint identification, target establishment, mathematical model development, configuration optimization, performance evaluation, parameter adjustment, and final design confirmation, we have demonstrated the effectiveness of our proposed methodology. Our network slicing architecture exhibits its capability to facilitate rapid and reliable communication, crucial for the myriad applications within Smart Cities IoT. Notably, our approach achieves low Round-Trip Time (RTT), minimal Packet Loss Rate, high Availability, and remarkable Throughput. Furthermore, our model demonstrates scalability and adaptability by efficiently managing numerous simultaneous connections while ensuring optimal resource utilization. This scalability is essential for meeting the evolving needs of Smart Cities, ensuring the network remains robust and responsive. Moreover, the robust security features of our model, including a strong 256-bit Encryption Strength and a high Authentication Success Rate, contribute to establishing a secure communication environment. Preserving the integrity of the communication network and safeguarding sensitive data are paramount considerations. The discussions in this section have provided nuanced insights into the implications of our findings, highlighting the favorable outcomes in terms of performance, scalability, and security measures. The versatility of our model across various scenarios and its ability to address the complex demands of Smart Cities IoT underscore its significance in the realm of 6G technologies. However, it is essential to acknowledge the limitations and recognize that the practicality of our model can be enhanced through ongoing refinement and testing in diverse environments. Future research endeavors should prioritize overcoming these constraints, exploring additional aspects of IoT integration in Smart Cities, and adapting the model to keep pace with the rapidly evolving technological landscape.

In summary, our network slicing framework represents a significant advancement in leveraging the potential of 6G technology to meet the intricate and ever-changing requirements of Smart Cities IoT. The favorable results obtained across various metrics underscore its potential to significantly enhance the efficiency, reliability, and security of communication networks in the intelligent urban infrastructures of the future.

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