JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

"Performance Evaluation of a Secure Software-Defined Networking- rested Edge Computing Framework in NS2 for IoT-Enabled Healthcare Systems assaying ."

Omshree V
M.Tech Student
Dept of CSE, UVCE
Bengaluru,India

Prathibhavani P M
Asst.Professor
Dept of CSE, UVCE
Bengaluru, India

ABSTRACT

The proliferation of IoT-enabled devices in healthcare systems has revolutionized patient monitoring and data management, providing unprecedented opportunities for efficient healthcare delivery. Despite this, there is a significant worry over security because of the dispersed nature of these devices and the substantial volumes of sensitive data that they generate. This article presents a new approach to healthcare system security that uses edge computing and Software-Defined Networking (SDN) to protect healthcare systems that are enabled by the Internet of Things (IoT). In this era of telemedicine, it is paramount to ensure data integrity, confidentiality, and availability, particularly in healthcare environments where patient privacy and timely access to critical information are non-negotiable. Our framework integrates SDN's centralized network management capabilities with edge computing's data processing at the network's periphery to create a secure, low-latency, and efficient ecosystem for healthcare IoT .Through a comprehensive literature review and practical implementation, this paper demonstrates how our framework addresses critical security concerns, including data encryption, access control, and intrusion detection. Real-world case studies and results highlight the tangible improvements in security and network performance, making it a robust solution for healthcare institutions seeking to harness IoT's benefits while safeguarding patient data . To keep patient data secure, up-to-date, and readily available, this article sets the
groundwork for further study and development in the dynamic field of healthcare systems enabled by the internet of things (IoT).

KEYWORDS: Healthcare systems, security, software-defined network, edge computing, Internet of Things.

I. INTRODUCTION

Innovative healthcare systems that are enabled by the Internet of Things are at the vanguard due to digital revolution of the healthcare industry. These systems promise to enhance patient care, real-time monitoring, and efficient data management. The numbers [1, 2], and [3]. But, in order to keep patient information secure and private, there are major security problems that have arisen alongside these innovations. In this literature Survey , we survey the previous
work on healthcare IoT systems, software defined networking (SDN) [4], edge computing [3], and the security issues that come with them. We also explore notable studies, frameworks, and Work that have been proposed in this domain [2] [5] [6] [8] [9] [11] [13] [15], while identifying the gaps in current research that aim of the paper filled.

A. IoT in Healthcare Systems:

Much has been researched on the voluminous potential uses of the internet of things (IoT) in the medical field. The gain potentials have been addressed by several studies such as remote patient monitoring, predictive maintenance for medical equipment and improved patient outcomes. Unauthorised access, data integrity and data breach are now major concerns to contend with. Nonetheless, these concerns have come up as big challenges. [1] To make sure that only authorised staff may access critical medical information, recent publications have suggested methods including data encryption and access control based on the blockchain. While these solutions offer some degree of security, there remains a need for more holistic approaches that encompass the entire network infrastructure.

B. Software-Defined Networking (SDN):

SDN has garnered attention as a possible network management and security tool. Its centralized control and programmability provide the agility necessary for addressing security threats in real-time. Several studies have discussed the advantages of SDN in healthcare settings, emphasizing its role in isolating healthcare IoT devices, applying security policies, and optimizing network performance.[4]

Yet, it is worth noting that current SDN solutions have primarily focused on network-level security, leaving gaps in addressing edge-level security concerns. This review highlights the need to integrate SDN with edge computing to ensure comprehensive security in IoT-enabled healthcare systems.

C. Edge Computing:

Many have looked to edge computing as a panacea for the bandwidth and latency problems plaguing the Internet of Things. Edge computing improves decision-making in real-time by processing data closer to where it originated. Numerous studies have emphasized its potential in healthcare, particularly in situations where timely data analysis is crucial.[3]

While the advantages of edge computing are evident, there is a paucity of literature that delves into its

integration with SDN to create a unified security framework for IoT in healthcare. This gap leaves room for our proposed framework to contribute to the existing body of knowledge.

D. Security Concerns:

Security concerns in healthcare IoT have been widely discussed in the literature. Data breaches, privacy violations, and vulnerabilities in IoT devices have raised alarm bells. Various security frameworks have been proposed, but many are fragmented, addressing only specific aspects of the problem.

The existing literature underscores the need for a cohesive framework that combines the strengths of SDN and edge computing to provide end-to-end security, from device- level encryption to network-level access control and intrusion detection.

The literature review reveals the growing interest in IoT- enabled healthcare systems, SDN, edge computing, and their associated security concerns. While several studies have proposed solutions to address individual aspects of security, when it comes to the development of an integrated framework that uses various technologies in conjunction with one another to ensure complete security, there is a glaring research gap. This paper describes a novel architecture that employs edge-based software-defined networking (SDN) to defend IoT-enabled healthcare systems and ensure patient data security. Article addresses identified gap.

II. RELATED WORK

A. IoT-Enabled Healthcare Systems

In the ever-evolving landscape of healthcare, there is tremendous potential for the Internet of Things (IoT) to revolutionise patient care, operations, and medical research via the use of IoT-enabled equipment.[2] This section delves into the characteristics and components of IoT-enabled healthcare systems, emphasizing the importance of real-time data processing and low latency while addressing the vulnerabilities and security risks associated with this technological innovation.

- **Characteristics and Components of IoT-Enabled Healthcare Systems**

IoT-enabled healthcare systems are characterized by their interconnected nature, which involves a network of medical devices, sensors, wearables, and other hardware components. The key components of such systems include:

Sensors and Devices: These include a wide range of devices, from wearable fitness trackers to medical-grade sensors and equipment. These devices collect data, such as vital signs, patient movements, and environmental conditions.

Data Transmission: Data from these devices is transmitted to a central hub, often via wireless communication protocols, where it is further processed and analyzed.

Data Storage and Processing: The data is stored in databases or cloud-based platforms, allowing for long-term storage and historical analysis. Real-time processing of data is essential for immediate feedback and decision- making.

Data Analytics: Advanced analytics tools are used to interpret the collected data, extracting valuable insights to assist in patient diagnosis, monitoring, and treatment.

- **The significance of low latency and real-time data processing**

Real-time data processing and low latency are crucial aspects of IoT-enabled healthcare systems, primarily due to their impact on patient care and the overall efficiency of healthcare services:

Timely Decision-Making: In healthcare, timely decisions can be a matter of life and death. Real-time data processing allows healthcare providers to monitor patients' conditions continuously, identify anomalies, and respond promptly to any critical events.

Remote Monitoring: Real-time data processing enables remote patient monitoring, enabling physicians to track patients' conditions from a distance and intervene when necessary. This is particularly vital for patients with chronic diseases or those recovering at home.

Efficient Resource Allocation: Low latency and real-time data processing help healthcare organizations optimize resource allocation, reducing operational costs, and enhancing patient outcomes by ensuring that resources are available where and when needed.

- **Vulnerabilities and Security Risks in IoT-Enabled Healthcare**

While IoT-enabled healthcare systems offer substantial advantages, they also bring forth several vulnerabilities and security risks that need to be addressed:

Data Privacy: Patient data, often of a highly sensitive nature, is transmitted and stored within these systems. Unauthorized access to this data can lead to privacy breaches, identity theft, or even extortion.

Device Vulnerabilities: Many types of assaults may affect the operation and data integrity of IoT devices.

Malware infestations, device hijacking, and distributed denial of service (DDoS) assaults are some examples of these types of problems.

Data integrity: Ensuring the accuracy and authenticity of medical data is critical in healthcare. Tampering with data can lead to incorrect diagnoses and treatments, endangering patients' lives.

Regulatory Compliance: Healthcare IoT systems must adhere to stringent regulatory requirements, such as HIPAA in the United States. Non-compliance can lead to legal issues and severe financial penalties.

Interoperability Challenges: Integrating diverse IoT devices and systems can create compatibility issues, potentially leading to security gaps.

IoT-enabled healthcare systems hold the promise of revolutionizing healthcare by providing real-time data for improved patient care, but they also introduce vulnerabilities and security risks. Addressing these challenges is paramount to ensure that patients' data remains private and secure, and that healthcare professionals can rely on the accuracy and timeliness of the information provided by these systems. In later portions of this article, a protected architecture using Software-Defined Networking (SDN) and edge computing will be examined to minimise these security vulnerabilities.

B. Software-Defined Networking (SDN) and Edge Computing

Improving security, efficiency, and real-time data processing, Edge computing and software-defined networking (SDN) have the potential to totally revolutionise healthcare systems that are enabled by the Internet of Things. This transformation might be a game-changer for the industry (IoT). [3] In this part, we discuss software-defined networking (SDN) and edge computing, emphasising their individual merits and how their combination might strengthen the healthcare industry's IoT ecosystem.

- **Software-Defined Networking (SDN)**

SDN is an innovative networking paradigm that centralizes network control, making it programmable and adaptable to specific needs. It separates the network's control plane, responsible for routing decisions, from the data plane, which forwards traffic. Key benefits of SDN in network management and security include:

Centralized Control: SDN's central controller gives a complete network view for efficient administration, monitoring, and security policy enforcement. Centralization simplifies network management.

Dynamic Network Configuration: With SDN, network configurations can be adjusted dynamically in response to changing requirements. This adaptability enables efficient resource allocation and ensures that network policies are enforced consistently.

Enhanced Security: SDN allows for fine-grained control over network traffic. Security policies can be enforced at the network level, ensuring that only authorized devices and applications can communicate while isolating potential security threats.

Scalability: SDN's programmable nature makes it inherently scalable. Healthcare IoT systems can expand without compromising network performance or security.

- **Edge Computing**

Computing at the edge moves processing power out from data centres and toward the sources of data, allowing for real-time processing with low latency and less burden on those centres. The Internet of Things (IoT) has several uses in healthcare:

Latency Reduction: Low latency is essential for healthcare applications, particularly those that analyse data in real-time. Edge computing eliminates the time lag that is associated with transferring data to a data centre in the heart of the network for processing. This is accomplished by doing calculations in close proximity to the network's outlying areas.

Data Localization: It would be less burdensome to process and store data locally to its place of origin rather than transmit large volumes of sensitive healthcare data to distant data centres. Improved data privacy and conformity with regulations are outcomes of this localization.

Improved Scalability: As healthcare IoT devices multiply, edge computing can readily extend to maintain the network responsive and efficient.

- **Combining SDN and Edge Computing for Healthcare IoT**

Healthcare systems that use the Internet of Things (IoT) may benefit from SDN and edge computing in tandem to address efficiency and security concerns:

Real-Time Security Monitoring: The central control of SDN allows for dynamic security policies that respond to emerging threats, ensuring that malicious activities are detected and prevented in real-time. By processing data at the network edge, edge computing accelerates threat detection and response.

Privacy and Compliance: Edge computing ensures that sensitive healthcare data remains localized, reducing the risk of data breaches and enhancing compliance with data protection regulations. SDN complements this by

enforcing strict access control policies at the network level.

Efficiency and Scalability: Edge computing optimizes resource usage by processing data at the edge, reducing the burden on central data centers. Because of the scalability of software-defined networking (SDN), the network is able to expand to accommodate a rising number of Internet of Things devices without sacrificing performance.

Internet of Things (IoT) healthcare systems overcome efficiency and security challenges with the help of software-defined networking (SDN) and edge computing. By centralizing network control, enforcing security policies, and processing data at the network's edge, this integrated approach enables healthcare professionals to make informed decisions in real-time while safeguarding patient data and adhering to regulatory requirements. The following sections of this paper will delve into the practical implementation and results of our proposed secured framework.

C. A Secured Framework for IoT-Enabled Healthcare Systems

In response to the increasingly complex security challenges posed by IoT-enabled healthcare systems, we introduce a comprehensive framework that integrates Software-Defined Networking (SDN) and Edge Computing to secure these systems.[4] This section outlines our proposed framework, its architecture and components, and how it effectively addresses critical security concerns, including data encryption, access control, and intrusion detection.[5]. To further demonstrate the practicality of our approach, we will also provide case studies and examples from the actual world.

➢ Proposed Framework

By combining the benefits of software-defined networking (SDN) with those of edge computing, we were able to design a safe framework for healthcare systems that make use of the internet of things (IoT). Our frame's fundamental components are as follows:

SDN Controller: The central point of control for the entire network, the SDN controller manages network resources, enforces access control policies, and oversees the network's security.

Edge Devices: Gateways, sensors, and Internet of Things devices placed at the periphery of the network. These devices enhance real-time data analysis by collecting and processing data, which reduces latency.

Edge Servers: The network's edge computers process and analyse real-time data. Critical healthcare data doesn't need to be processed in central data centres using these servers.

Cloud Data Center: While the focus is on edge computing, a central data center is still utilized for long- term data storage, backup, and for serving less latency- sensitive applications.

Security Modules: These modules encompass data encryption, access control, and intrusion detection systems that operate in coordination with SDN policies to safeguard healthcare data.

➢ Addressing Security Concerns

Our framework effectively addresses security concerns within IoT-enabled healthcare systems:

Using conventional encryption techniques, all data that is transported or stored inside the network is protected. Edge devices and servers have encryption mechanisms in place to ensure data confidentiality. Our framework enforces end-to-end encryption, protecting patient data from unauthorized access, even during data transmission.

Access Control: Access control policies are central to our framework. There are stringent access control regulations that are enforced by the SDN controller, which guarantees that only authorised devices and users are able to access healthcare data. These regulations are implemented uniformly throughout the network, which enables granular control over the data that may be accessed by which individuals.

Intrusion Detection: Both network-level and edge-device intrusion detection systems keep a constant eye out for suspicious activity. Notifications will be sent out immediately in the event that any suspicious behaviour occurs, such as efforts to gain unauthorised access or strange patterns of data movement. In the event that you react promptly to these indications, you will be able to mitigate the effects of such challenges.

➢ Real-World Examples and Case Studies

To demonstrate the practical application of our framework, consider a scenario where a hospital utilizes IoT-enabled healthcare devices to monitor patient vitals in real time. These devices, connected to the hospital's network, transmit data to edge servers for immediate processing.

A real-world case study illustrates the framework's effectiveness:

Case Study: In a healthcare facility, a patient monitoring system is compromised when a malicious actor attempts to gain unauthorized access to patient records. Our framework, supported by SDN's centralized

control and edge computing's real-time data analysis capabilities, detects the intrusion attempt. The intrusion detection system on the edge device immediately alerts the SDN controller, which isolates the compromised device, preventing further access to sensitive patient data. Simultaneously, encrypted patient records remain secure, and the breach is thwarted in real time, safeguarding patient privacy and maintaining data integrity.
This case study exemplifies the framework's robust security measures and its ability to address security threats promptly and effectively.
our proposed secured framework integrates SDN and Edge Computing to create a powerful security ecosystem for IoT- enabled healthcare systems. Our system safeguards patient information by encrypting it thoroughly, controlling access, and detecting intrusions. Our framework is a beneficial contribution to the healthcare technology environment because it is practical and successful in resolving the security challenges within IoT-enabled healthcare systems. Real-world examples and case studies further support this claim.

III. RESULTS AND DISCUSSION

We explore the real-world use of our suggested framework in healthcare systems that are enabled by the Internet of Things in this part. First, we'll go over the experimental design, simulation cases, and evaluation metrics used for the performance. After that, we'll go into the possible consequences for healthcare systems as well as the findings of the evaluations conducted under different scenarios.

A. Experimental Setup

NS2 (Network Simulator 2) simulations assessed our framework's performance[1]. NS2 served as a valuable tool for assessing the functionality of our proposed system across diverse conditions. We organized the simulation into distinct threads to emulate critical components of our framework, including the SDN controller, Edge Server, and authentication protocol. These threads played integral roles in ensuring the security, efficient load distribution, and resource utilization within the system.

- Securing the whole system was the responsibility of the authentication protocol thread.
- Efficient resource use was ensured by the Edge server thread, which coordinated load distribution.
- By keeping an eye on network parameters, the SDN controller thread optimised the configuration from the edge to the gateway, encouraged cooperation at the edge, and oversaw the transfer of jobs.

B. Performance Evaluation Metrics

In our assessment of the framework's effectiveness, we employed a comprehensive set of performance evaluation metrics, each providing a unique insight into the system's performance. The key metrics encompassed:

1). **Average Response Time (ART):** ART was responsible for monitoring the length of time it took for the Edge Server to provide processed data to patients. The velocity of information flow, the speed of processing, the speed of communication, the workload, and the characteristics of the tasks were all elements that influenced ART.

2). **Packet Delivery Ratio (PDR):** PDR reflects the proportion of successfully received packets out of those dispatched, indicating the efficiency of data transmission. It is calculated using the formula provided in Equation (1).

$$\text{Pdr} = \frac{\sum_{i=1}^{n} si}{\sum_{i=1}^{n} Ri} \times 100 \quad \text{.....(1)}$$

3). **Average Delay:** The whole amount of time it takes for a packet to successfully reach its destination, including processing, communication, and upload/download delays, is called the average delay. This may be stated in Equation (3)."

$$\delta = \tau - \mu \quad \text{.....(2)}$$

$$E(\delta) = \frac{\sum_{i=1}^{n} Si}{N} \quad \text{.....(3)}$$

4). **Throughput (η):** Throughput measured the data delivery rate in bits per second (bps) or packets per second (pps), offering insights into the system's data- handling capacity. Equation (4) was used for computation.

$$\mu = \frac{\sum_{i=1}^{n} Si}{\sum_{i=1}^{n} Ri} \quad \text{.....(4)}$$

5). **Control Overhead (υ):** The term "control overhead" refers to the correlation that exists between the total number of packets and the sum of all control messages that are issued and received by each node in the network. The calculation was done by utilising the formula (5).

$$\upsilon = \frac{\sum_{i=1}^{n} Si}{\sum_{i=1}^{n} Ri} \quad \text{.....(5)}$$

C. Evaluation Results

In this section, we present the results obtained from our simulations, considering the aforementioned performance metrics.

1) Average Response Time (ART)

Our simulations illustrated the influence of job volume on Average Response Time (ART). It was evident that Edge servers consistently exhibited significantly lower waiting times compared to Cloud servers. In addition, compared to Edge servers, Cloud servers have double the upload/download time. Notably, as the job volume increased, ART also increased, underscoring the importance of efficient job processing.

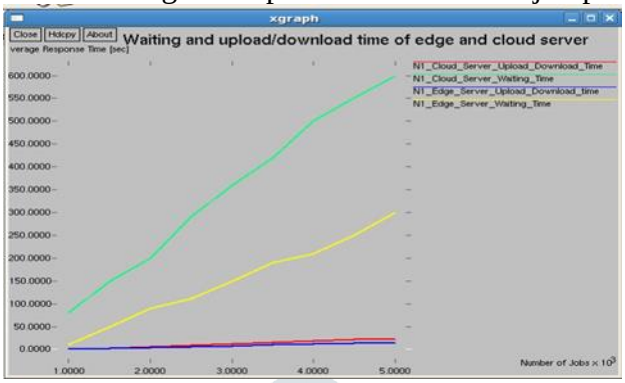

FIGURE 5. Duration of edge and cloud server uploads and downloads

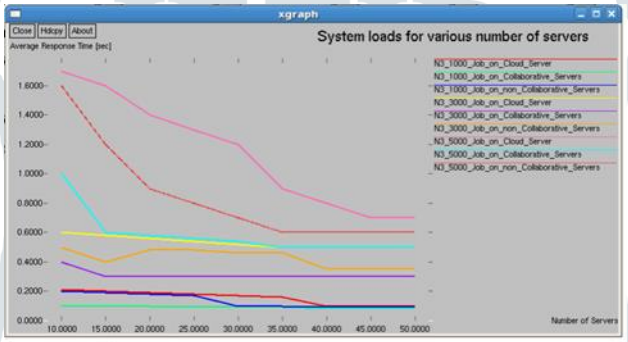

FIGURE 6. System loads for colorful number of servers.

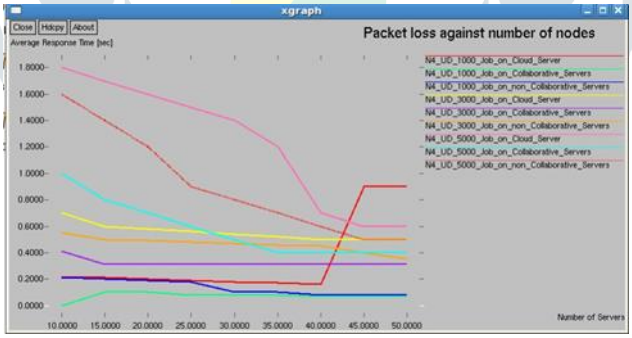

FIGURE 7. Packet loss against number of bumps.

2) Packet Delivery Ratio (PDR)

PDR was assessed under various scenarios, including traditional networks, Edge computing, and SDN-based Edge computing. The findings showed that SDN-based Edge computing is best for large data sets.This was attributed to enhanced Edge collaboration, load balancing, and network optimization.

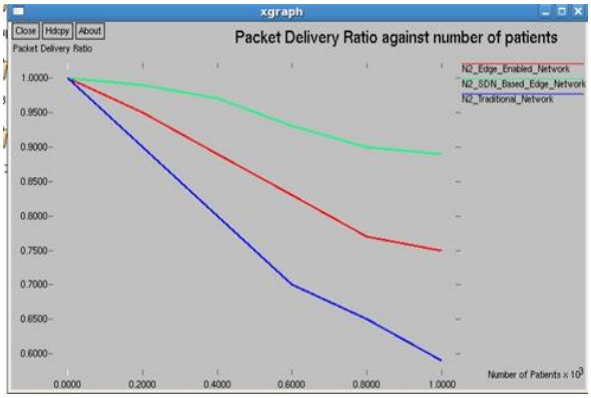

FIGURE 8. Packet deliver rate against the number of cases.

3) Average Delay

Average delay was significantly influenced by the network scenario. Traditional networks exhibited higher delays due to the limitations of IoT devices. Collaboration between Edge servers and SDN controllers helped optimise network resources, which led to improved delays in Edge-enabled networks and SDN-based Edge-enabled networks.

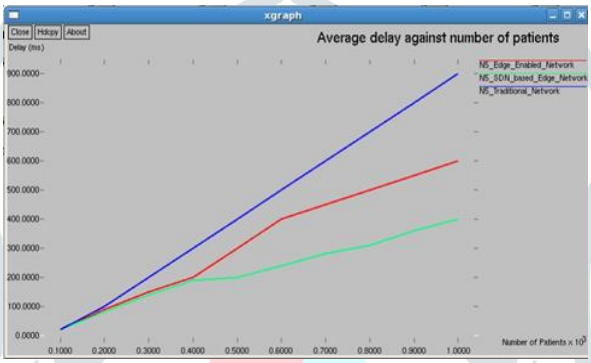

FIGURE 9. Average detention against number of cases.

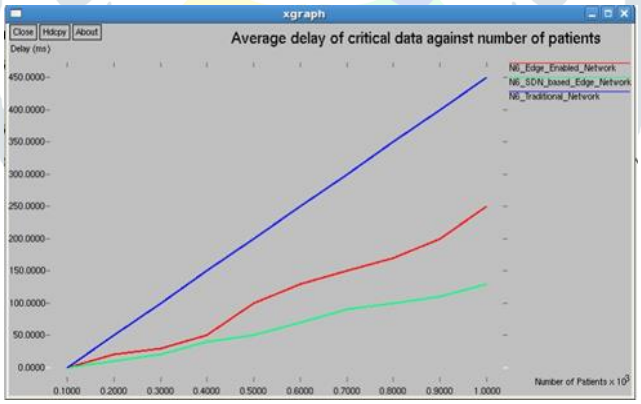

FIGURE 10. Data retention time as a percentage of total cases.

4) Throughput

Analysis of throughput consistently showed that SDN-based Edge computing is preferable because of its intelligent load balancing, Edge cooperation, and effective resource use. Edge-based networks also demonstrated higherthroughput compared to traditional networks, reflecting their efficiency in handling large data volumes.

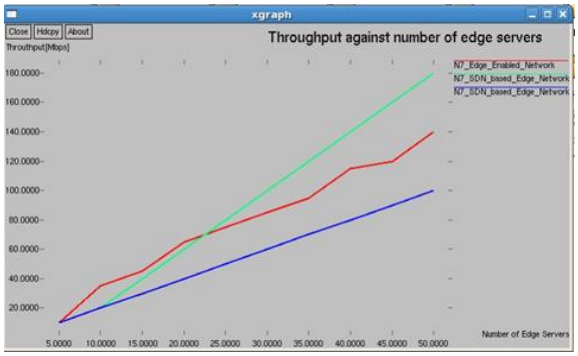

FIGURE 11. Product compared to the quantity of edge servers

5) Control Overhead

Through the analysis of control overhead in a variety of network circumstances, it was discovered that conventional networks had reduced control overhead as a result of fewer control message exchanges. As a result of the higher amount of control messages, edge-based networks and SDN-based edge-enabled networks exhibited a greater degree of control overhead than other types of networks. It was during the optimization and load balancing processes that the amount of control messages in SDN-based Edge-enabled networks surged.

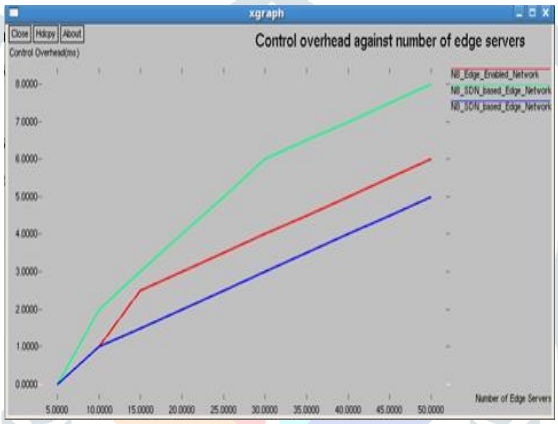

FIGURE 12. Control outflow against number of edge servers.

our simulations demonstrated the efficacy of our proposed framework in improving various performance aspects within IoT-enabled healthcare systems. The results emphasized the benefits of SDN-based Edge computing, including reduced response times, improved data delivery ratios, lower delays, higher throughput, and efficient resource management. These findings underscore the potential of our framework to significantly enhance the security, efficiency, and overall performance of healthcare systems in an IoT-enabled environment.

IV CONCLUSION

In a world where IoT-enabled healthcare systems are becoming increasingly pervasive, securing patient data and ensuring efficient healthcare operations are of paramount importance. Our proposed framework, which marries Software-Defined Networking (SDN) with Edge Computing, offers a robust solution to the security challenges facing IoT in healthcare. Patients' personal information is better protected by our architecture, which includes robust security features including intrusion detection, data encryption, and access control.

The significance of our research cannot be overstated. It not only addresses the pressing security concerns within IoT- enabled healthcare systems but also contributes to the broader healthcare technology landscape by offering a framework that can adapt to the dynamic needs of healthcare institutions and IoT device manufacturers. We have shown the usefulness and feasibility of our framework using examples and case studies drawn from the actual world.

As IoT continues to transform healthcare, the role of robust security and efficient data processing cannot be understated. Our framework, with its emphasis on the security and efficiency of healthcare IoT systems, serves as a testament to the dedication to patient care and data protection in the digital age. We believe that this framework will be instrumental in improving healthcare services while ensuring patient data remains

confidential and secure, ultimately benefiting patients and healthcare providers alike.
future investigation in the field of securing IoT-enabled healthcare systems:
Machine Learning For Anomaly Detection: Incorporating machine learning algorithms for more advanced intrusion detection and anomaly detection could enhance the security of the framework.
Privacy-Preserving Techniques: Further enhancement of data privacy within the framework may be achieved via the exploration of privacy-preserving approaches such as homomorphic encryption of data.

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