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Analysis of a Robust 5G-IoT Architecture for Intelligent Healthcare Applications

Ms. SAKSHI AHUJA
Assistant Professor, Department of Computer Science & Engineering, Dronacharya College of Engineering, Gurugram, Haryana
sakshi.ahuja@ggnindia.dronacharya.info

MS. MANU SHARMA
Assistant Professor, Department of Computer Science & Engineering, Dronacharya Group of Institutions, Greater Noida, Uttar Pradesh
manu.sharma@gnindia.dronacharya.info

Abstract

The Internet of Things (IoT) has revolutionized the healthcare sector by providing real-time monitoring and diagnosis capabilities. However, there are challenges such as a lack of standard frameworks, network resource optimization, energy-efficient resources, and malicious data. To address these issues, an enhanced system framework is proposed, which is integrated into four modules. The first module provides a methodology for enhancing 5G-IoT smart healthcare applications, with a customized architecture incorporating various sensors, technology standards, and communication protocols. The second module offers an intelligent approach for network resource optimization and analysis, while the third module improves energy efficiency through an improved Optimal Enumeration Algorithm. The fourth module tackles malware threats in 5G-IoT healthcare applications using distinct Convolutional Neural Network (CNN) models.

Keywords: IoT, Artificial Intelligence, Machine learning, Information, Healthcare.

Introduction

The IoT has revolutionized healthcare by providing real-time monitoring and diagnosis. However, challenges include lack of standard frameworks, network resource optimization, energy efficiency, and malicious data. An enhanced system framework is proposed, integrating four modules for enhanced 5G-IoT smart healthcare applications, network resource optimization, and malware threat mitigation [1-5].

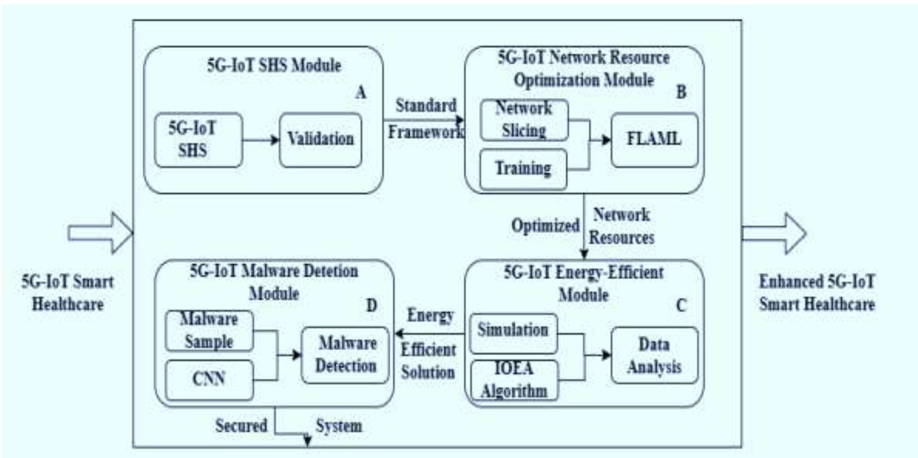

Fig.-1 Block Diagram of Proposed system

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The goal is to provide a reliable solution for 5G-IoT smart healthcare systems, enhancing network connectivity with low latency, energy efficiency, reliable resources, and security issues. The problem statement includes suggestions for an architecture, data analysis, resource management, energy-efficient network techniques, and network security mechanisms. 5G-IoT is crucial for remote monitoring applications in healthcare, enabling high-speed networks and data transmission for patients. After reviewing 240 articles, 120 were chosen from reputable databases [6-10].

Gaps Identified in the Existing Work

Research gaps in 5G-IoT integration include improving connectivity, enhancing data transfer, and supporting various industries. Real-time analysis in smart healthcare presents opportunities for transforming patient care and improving medical outcomes. However, the growing number of IoT devices increases security risks. Designing IoT devices with low-energy components and optimized hardware can reduce energy use. A system for managing 5G-IoT in smart healthcare should consider interoperability, remote patient monitoring, and emergency response. Effective big data analysis techniques, efficient mathematical methods, and machine learning algorithms are also needed. Resource management techniques, a GDPR-based framework for smart healthcare, and an intelligence-based model can be explored for improving performance and reliability [11-15].

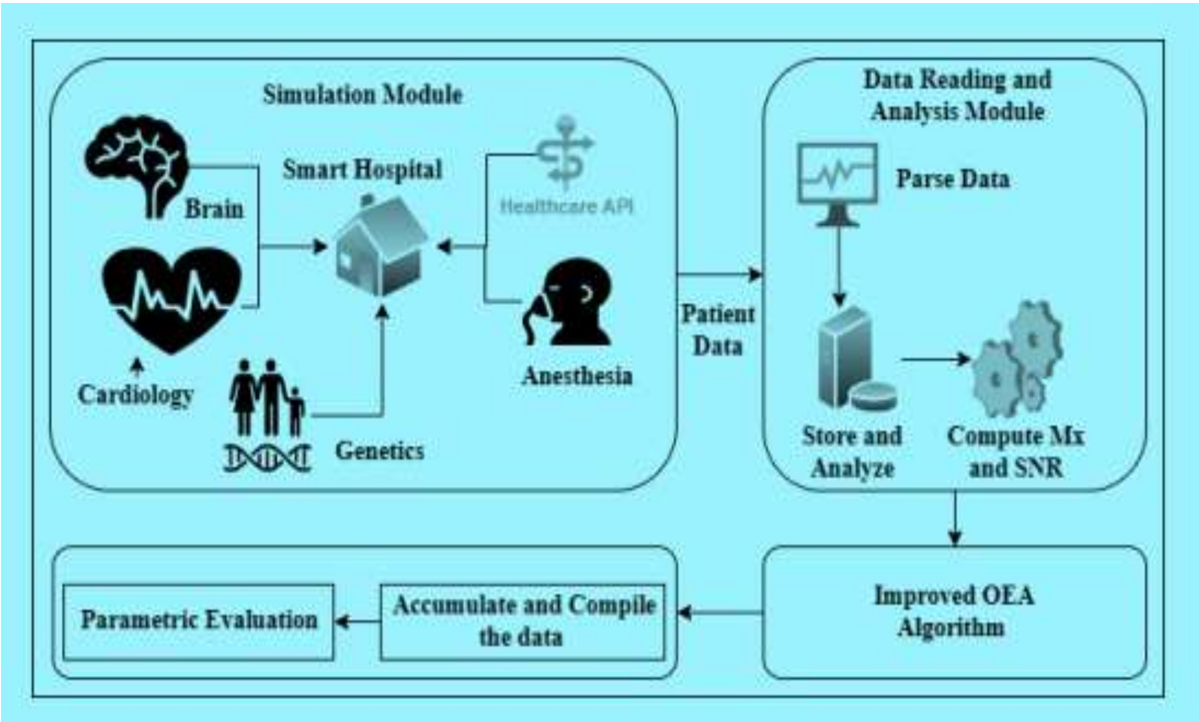

Fig.-2 Proposed Methodology of the System

A Proposed System Framework for 5G-IoT Based Smart Healthcare System

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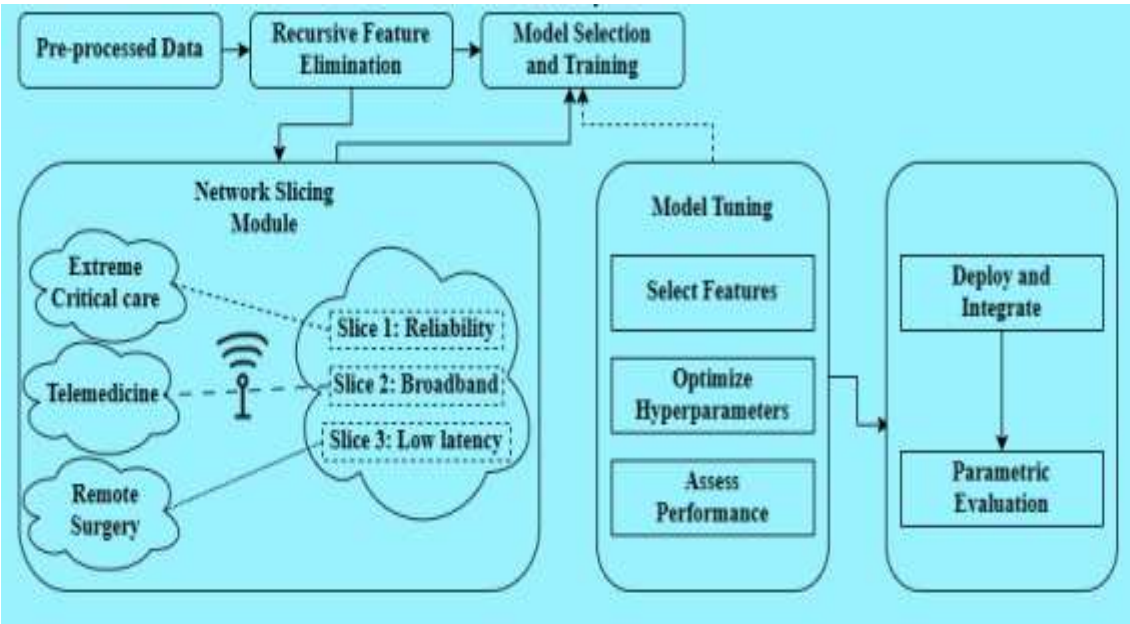

Fig.-3 Proposed Methodology of the System

This paper presents a comprehensive framework designed to enhance healthcare systems using the synergy of **5G and IoT technologies**, addressing existing limitations in latency, energy efficiency, scalability, and security [16-20].

Key Concepts and Motivation

- **Smart Healthcare** leverages digital tech for more personalized, preventive, and cost-effective healthcare.
- **IoT** enables real-time monitoring, emergency handling, and health data sharing.
- **5G** overcomes IoT limitations with high bandwidth, low latency, and reliable connectivity [21-25].
- Challenges include **data privacy**, **device integration**, and **network efficiency**.

Proposed 5G-IoT Smart Healthcare System (5G-IoT-SHS)

A **four-module framework** is proposed to address various challenges:

1. **System Architecture Module (A)**: Combines 5G and IoT for real-time, low-latency healthcare communication. Validated using Cisco Packet Tracer.
2. **Network Resource Optimization Module (B)**: Uses **network slicing** and **machine learning (FLAML)** for efficient resource management.
3. **Energy-Efficient Module (C)**: Introduces an improved **Optimal Enumeration Algorithm (OEA)** and **Proximity-based Services (ProSe)** to enhance **D2D communication** and reduce power consumption.
4. **Malware Detection Module (D)**: Uses **Convolutional Neural Networks (CNNs)** to detect and classify malware threats in healthcare systems.

Proposed Layered Architecture

The system follows a **4-layer architecture** for structured data flow and management:

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1. **Perception Layer**: Uses clinical and non-clinical sensors to collect health data; communicates via Zigbee, LoRaWAN, Bluetooth, etc.
2. **Network Layer (5G Layer)**: Transfers data via 5G, includes MEC servers for edge processing, and utilizes protocols like RLC, MAC, and PHY.
3. **Cloud Layer**: Stores and processes data with cloud services; ensures authorized access and remote consulting.
4. **Service Access Layer**: Interfaces for medical staff and patients via apps; supports remote diagnosis and treatment using protocols like MQTT, HTTP, COAP.

Experimental Setup

- **Cisco Packet Tracer (CPT)** is used to simulate the healthcare network.
- Simulation includes sensors, gateways, 5G links, and cloud connections.
- Steps: Add gateway → connect devices → link end-user systems → test the setup.

Results and Analysis

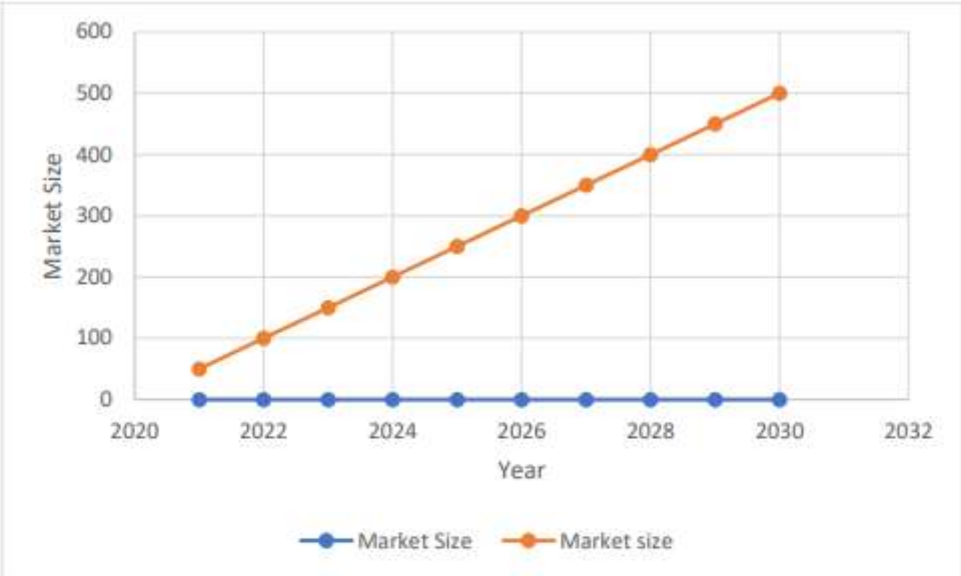

Fig.-4 Growth of Smart Healthcare till 2030

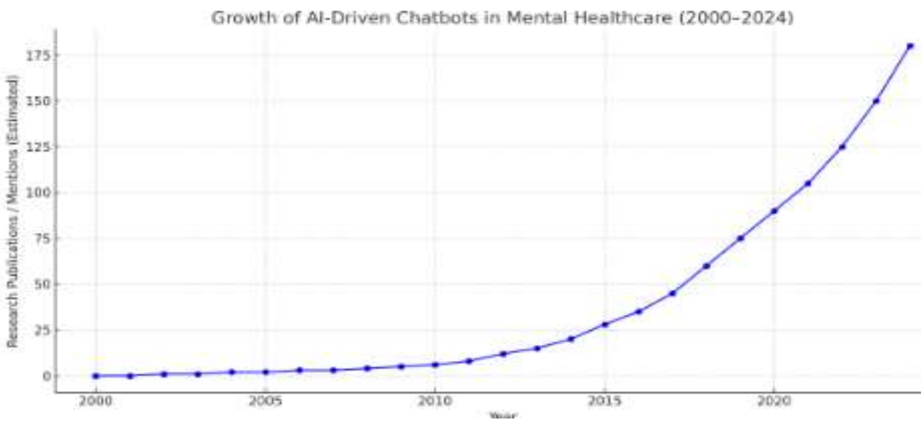

Fig.-5 Growth trend of AI-driven chatbots in mental healthcare from 2000 to 2024

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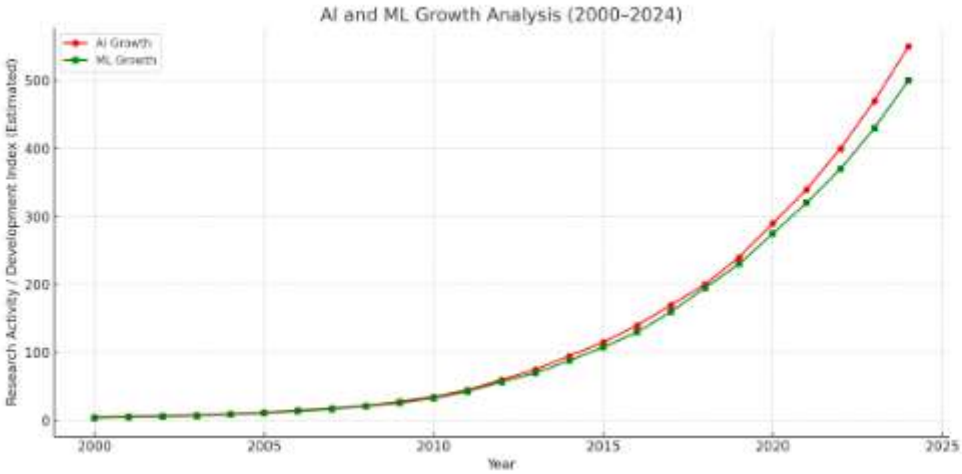

Fig.-6 Comparative growth of Artificial Intelligence (AI) and Machine Learning (ML) from 2000 to 2024

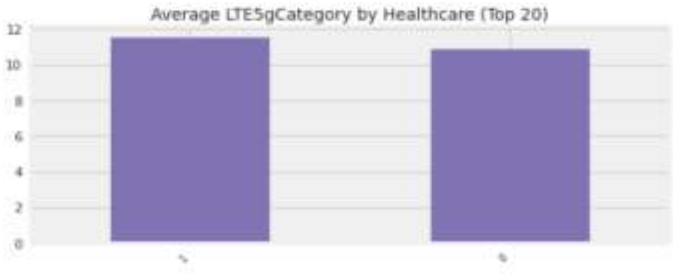

Fig.-7 Average LTE5g Category by Healthcare

The growing demand for smart healthcare systems is driven by factors like aging populations, pandemics, and remote patient monitoring. Traditional healthcare infrastructure struggles with latency, bandwidth, and scalability. The proposed 5G-IoT architecture aims to address these issues by ensuring real-time data acquisition, transmission, and processing. The architecture includes a Perception Layer (IoT Layer) with devices like wearable sensors, implantables, and mobile health apps, a Network Layer (5G Core) with technologies like 5G New Radio, Network Slicing, and Edge Computing, and a Processing Layer (Edge + Cloud) with edge analytics and cloud analytics. The application layer includes mobile apps, dashboards, and alert systems.

Conclusion

The paper emphasizes the growing impact of **5G-enabled IoT (Internet of Things)** technology, particularly in **smart healthcare systems**. It highlights how 5G enhances real-time communication, automation, and reliability in various domains, including healthcare.

Key Contributions of the Research:

- **Proposed a novel 5G-IoT-based Smart Healthcare System (5G-IoT-SHS)** framework with four functional layers.
- **Validated the framework** using Packet Tracer simulation.

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- **Introduced an intelligent method** for optimizing network resources.
- Utilized **FLAML (Fast Library for Automated Machine Learning)** to evaluate performance.
- Achieved **98.65% accuracy with LGBM algorithm** and minimal time delay.
- Proposed an **improved Optimal Enumeration Algorithm (OEA)** using a greedy approach to optimize resource allocation.
- Integrated **Proximity-based Service (ProSe)** for energy-efficient D2D (Device-to-Device) communication.
- Designed a **CNN-based malware detection framework** for healthcare IoT devices.
- Demonstrated **low computational overhead**, suitable for resource-constrained devices.
- **EfficientNet outperformed other CNN models** with highest accuracy (96% for Malimg and 95% for MaleVis datasets), while **VGG16 showed the lowest** (80% and 93%).

Future Scope:

- Expand to **more features and applications** of 5G-IoT in healthcare.
- Explore **IoE (Internet of Everything)** for malware detection, considering a broader range of devices.
- **Shift to cloud-based storage** for better scalability and remote access.
- Investigate **ethical aspects** of resource optimization.
- Explore **real-time remote surgeries** using 5G-IoT for critical healthcare innovations.

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