A Comprehensive IoT-Fog-Cloud Architecture for Real-Time Healthcare Monitoring

Abstract

The rapid integration of Internet of Things (IoT) devices in healthcare has enabled continuous patient monitoring and data-driven medical decisions. However, relying solely on cloud-based architectures introduces latency, network congestion, and energy inefficiency, which can be detrimental in critical healthcare scenarios. To address this, we propose a hybrid IoT-Fog-Cloud architecture that leverages edge (fog) computing for real-time processing of critical medical data while using cloud resources for long-term storage and analytics. The system employs Weighted Sum Method (WSM) for task prioritization and Modified Best Available Resource (MBAR) algorithm for efficient resource allocation. Simulations using iFogSim demonstrate reduced latency, improved resource utilization, and lower miss ratios compared to traditional cloud-only approaches.

1. Introduction

Healthcare applications increasingly depend on real-time data collection through IoT devices such as ICU monitors, wearables, and biosensors. While cloud computing provides scalable processing and storage, its reliance on distant data centers introduces unacceptable latency for time-sensitive tasks like arrhythmia detection or oxygen level monitoring.

Problem Statement: Current cloud-centric systems face high latency, energy inefficiency, and limited scalability for real-time healthcare needs.

Objective: To design and evaluate a Cloud-Fog hybrid architecture that ensures low-latency, secure, and scalable healthcare monitoring through intelligent task scheduling and allocation.

2. Why This is an Edge Problem

Healthcare IoT systems require instantaneous response to emergencies (e.g., hypoxia alerts, ECG abnormalities). Transmitting all data to the cloud is inefficient. Fog/Edge nodes (gateways, local servers) enable processing closer to data sources, ensuring:

- Ultra-low latency

- Context-aware decision-making

- Reduced bandwidth use

- Enhanced privacy and reliability

3. System Architecture

Layers

1. IoT Layer (Things) – Devices like wearables and biosensors that collect vitals.

2. Sink Layer – Mobile devices and gateways aggregating and forwarding data.

3. Fog Layer – Equipped with Fog Broker modules for scheduling, allocation, and emergency detection.

4. Cloud Layer – Used for long-term storage and analytics.

4. Algorithms

4.1 Weighted Sum Method (WSM) – Task Prioritization

Priority = $w1 \times$ Latency + $w2 \times$ Energy + $w3 \times$ Urgency

4.2 Modified Best Available Resource (MBAR) – Task Allocation

Dynamically allocates tasks to available fog nodes while preventing overload and ensuring urgent tasks are handled first.

5. Simulation Plan

- Simulator: iFogSim (Java-based)

- Tasks: 300 healthcare tasks (ECG, fall detection, vitals monitoring)

- Algorithms: WSM (priority), MBAR (allocation)

- Scenarios: Random Allocation vs WSM vs WSM+MBAR

Metrics: Latency, Miss Ratio, Average Delay, Cost per Execution, Resource Utilization

6. Results & Observations

- Cloud-only models suffered from high latency and deadline misses.

- Fog-based hybrid model reduced latency significantly.

- WSM ensured critical tasks met deadlines.

- MBAR improved resource distribution and utilization.

- Lower cost due to reduced cloud dependence.

7. Benefits of Fog Integration

- Real-time emergency handling.

- Enhanced privacy/security at local nodes.

- Reduced bandwidth consumption.

- Scalability through distributed resource allocation.

- Improved quality of healthcare services.

8. Conclusion & Future Work

The proposed IoT-Fog-Cloud system successfully reduces latency and improves healthcare task reliability through intelligent scheduling and allocation. Simulation results validate the effectiveness of WSM+MBAR.

Future Work:

- Deploy a physical prototype (Raspberry Pi/STM32 + sensors).

- Integrate real-time alerting system for hospitals.

- Test with live patient data streams for validation.

9. Team Contributions

- Nikshith: Introduction & Problem Statement

- Hemanth: Architecture & Edge Solution

- Akhil: Algorithms (WSM + MBAR)

- Tejeswar: Benefits, Summary, Conclusion