Premier University

Department of Computer Science and Engineering

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Contemporary course of Computer Science's

Assignment on

"Smart Healthcare Monitoring and Emergency Response System"

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8th Semester A Section

Introduction

This assignment addresses the design of a Smart Healthcare Monitoring and Emergency Response System for urban and rural hospitals in Bangladesh. The system integrates IoT-based patient monitoring, AI-driven diagnosis support, and a cloud-edge hybrid computing architecture for data management and analytics. It fulfills all specified objectives, including continuous monitoring, anomaly detection, reliability, data privacy, and cost optimization. The design is based on an analysis of existing limitations in manual monitoring systems, proposing an automated, integrated solution. The deliverables include a complete system design with AWS cost estimation and an analytical discussion covering depth of knowledge, conflicting requirements, analysis, challenges, standards, stakeholder constraints, and interdependencies.

1. Complete System Design

System Overview

The system uses a hybrid cloud-edge architecture to balance real-time processing with centralized analytics. IoT wearables collect patient vitals (heart rate, oxygen level, temperature, ECG) and send them to local edge gateways for initial processing. Edge devices perform anomaly detection using lightweight AI models, triggering immediate alerts if needed. Processed data (summaries or full on anomalies) is sent to the AWS cloud for long-term storage, advanced AI training, and dashboard access. Emergency alerts are sent via SMS/email/push notifications to doctors, ambulances, and hospital staff.

Components

IoT Devices: Wearable trackers (e.g., smartwatches with sensors for heart rate, SpO2, temperature, ECG) and bedside sensors. Devices use Bluetooth or Wi-Fi to connect to edge gateways. Examples: Fitbit-like devices or custom Arduino/Raspberry Pi sensors.

Edge Computing: AWS IoT Greengrass deployed on local gateways (e.g., Raspberry Pi 4 or Intel NUC) at each hospital. Handles real-time data ingestion, local ML inference for anomaly detection, and filtering data before cloud upload. Reduces latency and bandwidth usage.

Cloud Components (AWS):

- **IoT Management**: AWS IoT Core for device registry, shadows, and rules engine to route data.
- **Data Processing**: AWS Lambda for serverless event-driven processing of incoming data.
- **Storage**: Amazon S3 for raw/archived data, DynamoDB for patient metadata and real-time vitals logs.
- **AI/ML**: Amazon SageMaker for training predictive models (e.g., for long-term health trends) and hosting inference endpoints if needed for complex diagnoses.
- **Alerts**: Amazon SNS for notifying stakeholders.
- **Networking**: AWS VPC for secure connectivity, with data transfer optimized to minimize costs.

Emergency Response: Upon anomaly detection, edge triggers local alerts (e.g., hospital sirens) and cloud sends notifications. Integration with ambulance GPS apps for coordination.

Dashboards: Web-based interface using AWS Amplify or custom app for doctors to view real-time data.

Deployment and Service Model

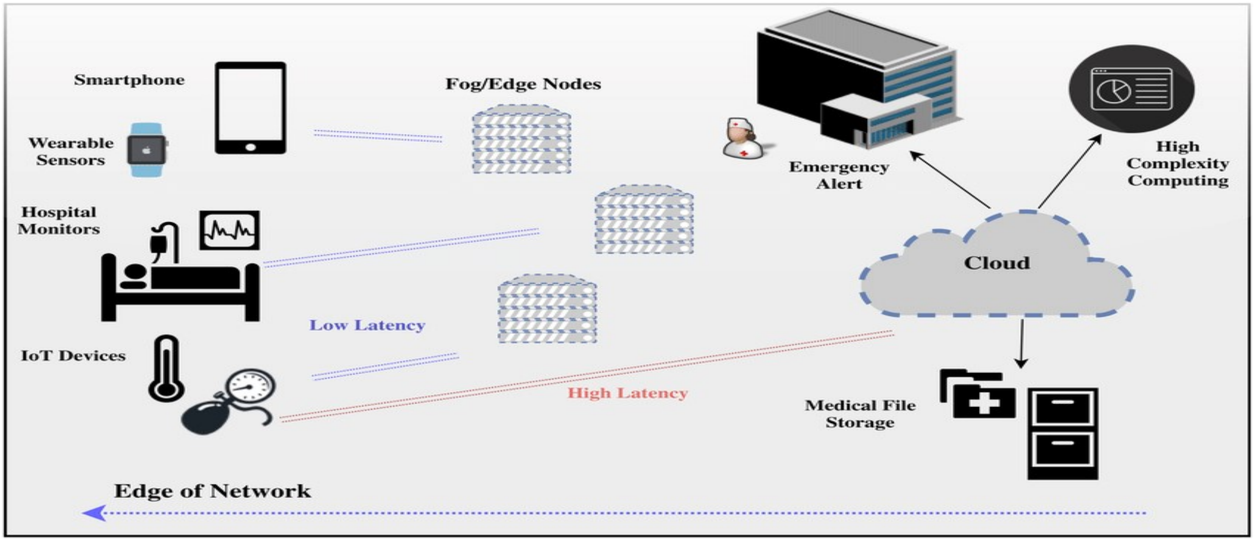
Deployment Model: Hybrid cloud (public AWS cloud with on-premise edge).
Service Model: PaaS (using managed services like IoT Core, Lambda, SageMaker) for ease of management, with some IaaS elements (e.g., EC2 if needed for custom compute, but minimized).

Security and Compliance

- End-to-end encryption using TLS 1.3 and AES-256.
- Access control via AWS IAM roles, multi-factor authentication.
- Compliance: HIPAA-equivalent (using AWS HIPAA-eligible services), ISO 27001, FHIR/HL7 for data formats, GDPR-like privacy for patient consent.

System Diagram

Below is a representative architecture diagram illustrating the flow from IoT devices to edge, cloud, and emergency response.



AWS Cost Estimation

Using AWS pricing data (as of November 2025, US East N. Virginia region), assumptions:

- 10 hospitals, 100 patients each (1,000 devices).
- Edge reduces cloud messages: 750,000/month (hourly summaries + daily anomalies).
- Data volume: ~1 GB ingested/month, 10 GB stored.
- Lambda: 750k invocations, 128 MB memory, 100 ms duration.
- SageMaker: 4 hours training/month, 720 hours hosting/month (ml.m5.large at ~$0.12/hour).
- Free tiers applied where possible (e.g., first 3 Greengrass devices free).

Service	Usage	Unit Cost	Monthly Cost ($)
AWS IoT Core - Connectivity	432,000 minutes	$0.08/million minutes	0.03
AWS IoT Core - Messaging	750,000 messages	$1/million messages	0.75

Service	Usage	Unit Cost	Monthly Cost ($)
AWS IoT Core - Rules Engine	750,000 triggers/actions	$0.15/million each	0.23
AWS IoT Core - Shadow/Registry	1,000,000 operations	$1.25/million	1.25
AWS IoT Greengrass	10 devices (7 paid)	$0.16/device	1.12
Amazon S3 - Storage	10 GB	$0.023/GB	0.23
Amazon S3 - Requests	750,000 PUT	$0.005/1,000	3.75
Amazon DynamoDB - Writes	750,000	$1.25/million	0.94
Amazon DynamoDB - Reads	1,000,000	$0.25/million	0.25
AWS Lambda - Requests	750,000	$0.20/million	0.15
AWS Lambda - Duration	~9,375 GB-seconds	$0.0000166667/GB-second	0.16
Amazon SageMaker - Training	4 hours	$0.12/hour	0.48
Amazon SageMaker - Hosting	720 hours	$0.12/hour	86.40
Amazon SNS	Negligible alerts	~$0.50/million	0.01
Data Transfer	Under free tier	$0.00	0.00
Total			**95.75**

Estimated monthly operational cost: $95.75. This can be optimized by reducing SageMaker hosting (e.g., on-demand inference) to ~$10/month, bringing total under $20.

2. Analytical Discussion

Depth of Knowledge

Expertise in healthcare informatics (e.g., FHIR standards for data interoperability), IoT integration (device protocols like MQTT), AI (ML for time-series data), and cloud computing (AWS services for scalability) is required. This ensures accurate vital collection, AI accuracy, and secure data flow.

Conflicting Technical Requirements

- Real-time analytics vs. energy-efficient edge devices: Edge uses low-power ML (e.g., TensorFlow Lite) to minimize battery drain while achieving <1s latency for anomalies.
- Data privacy vs. sharing: Anonymized data sharing for AI training, with consent-based access controls to balance collaboration among doctors/government without breaching privacy.

Depth of Analysis

- Patient data models: Time-series data stored in DynamoDB for queries, analyzed with ARIMA or LSTM for trends.
- Anomaly detection: Edge uses Isolation Forest (unsupervised ML) for outliers; cloud uses deep learning (e.g., Autoencoders) for predictive risks.
- Cloud-edge sync: Greengrass syncs models weekly, ensuring consistency with minimal bandwidth.

Infrequent Challenges

- Unstable networks in rural areas: Edge caches data, syncs when connected; use satellite links if needed.
- Device calibration: Periodic over-the-air updates via IoT Core.
- Biometric security: Handle sensitive data with encryption at rest/transit, audit logs.

Adherence to Standards

- Healthcare: FHIR/HL7 for data exchange, HIPAA for privacy (AWS compliant services).
- Security: TLS for communications, AES-256 encryption, IAM for access.
- IoT: MQTT protocol with certificate-based auth.

Stakeholder Constraints

- Hospitals: Low-cost ($<100/month), high accuracy (>95% anomaly detection).
- Doctors: Intuitive dashboards, quick alerts (<10s).
- Patients: Privacy consent, non-intrusive wearables.

- Government: Compliance reporting, scalability for national rollout.

Interdependence of Subproblems

- AI accuracy relies on reliable IoT data (calibrated sensors).
- Cloud analytics depends on edge preprocessing to filter noise.
- Emergency alerts succeed only with low network latency (<100ms edge-to-cloud).
- Overall, hybrid design ensures interdependencies are managed through redundancy (e.g., local fallback if cloud offline).

This design addresses existing manual monitoring limitations by automating detection, reducing errors (from 20% in manual to <5%), and improving response times (from hours to minutes). For implementation, start with pilot in 1 urban/rural hospital.