Smart Real-Time Health Monitoring System

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***Abstract*: In today's digital healthcare environment, real-time health monitoring and efficient communication are essential for improved patient care. This research paper presents *MediPulse*, a Healthcare Management System that integrates smartwatch-based vitals tracking with intelligent transcription and translation mechanisms for enhanced accessibility. Health metrics such as ECG, real-time heart rate, and sleep analysis are collected and securely transmitted to doctors for timely analysis and informed decision-making. The system supports online consultations, where patient-doctor conversations are transcribed using advanced speech recognition techniques. These conversations are then accurately aligned with audio using forced alignment for word-level precision, and translated into both Urdu and English to ensure accessibility for local users. This dual-language support enables accurate record keeping and facilitates communication in native-language contexts. Prescriptions are generated and digitally transmitted to pharmacies, ensuring medication availability and reducing manual processing. MediPulse enhances the inclusivity, efficiency, and effectiveness of remote healthcare services.**

***Keywords:* Speech Recognition, Transcription, Urdu Translation, Smartwatch Health Monitoring, Health-care Management System, Remote Consultations,**

INTRODUCTION

The healthcare sector faces critical challenges in managing patient data, ensuring real-time health monitoring, and facilitating seamless communication between patients, doctors, and pharmacies. Traditional healthcare systems lack the necessary integration to efficiently utilize wearable technology for proactive medical decision-making. The MediPulse initiative addresses these limitations by developing a comprehensive healthcare management system that leverages advanced technologies to enhance healthcare accessibility, efficiency, and security.

With the increasing adoption of wearable devices such as smartwatches, real-time tracking of vital health metrics including heart rate, electrocardiograms (ECG) [1], and Sleeping Analysis [2] has become essential for early diagnosis and personalized treatment. Existing healthcare infrastructures struggle to incorporate and process this continuous stream of patient data effectively. MediPulse bridges this gap by enabling real-time health data transmission, allowing healthcare providers to make informed medical decisions swiftly.

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This initiative aligns with the United Nations Sustainable Development Goals (SDGs), particularly SDG 3 [3]: Good Health and Well-being and SDG 9: Industry, Innovation, and Infrastructure [4]. By facilitating timely access to medical consultations and improving the service of patient-provider interactions, MediPulse significantly enhances the efficiency of healthcare delivery. The system also ensures secure financial transactions through an integrated payment gateway, allowing patients to book consultations, track health status, and access medications via an intuitive web and mobile platform.

To strengthen the security and reliability of healthcare services, MediPulse incorporates several critical modules, including transcription services that convert consultations into text for future reference, receptionist support for appointment scheduling and billing, bank and payment gateway integration for seamless financial transactions, and pharmacy management to streamline prescription fulfillment. By implementing these technological advancements, MediPulse aims to transform healthcare accessibility, optimize medical workflows, and ensure high standards of patient care.

MediPulse's scalable and cloud based architecture ensures that healthcare providers can access patients records securely from any location, facilitating telemedicine and remote consultations [5]. This is particularly beneficial for rural or underserved areas where access to specialized healthcare is limited. Through its user friendly interface and automation driven workflows, MediPulse empowers both patients and medical professionals with the tools needed for efficient, data driven healthcare management, paving the way for a smarter, more connected healthcare ecosystem [6].

Study Contributions

This paper presents MediPulse, a real-time healthcare management system integrating smartwatch-based vital sign monitoring with secure cloud infrastructure. It incorporates multilingual speech transcription and Urdu–English translation with word-level alignment to enhance accessibility during remote consultations. Experimental evaluation of Urdu ASR performance demonstrates the system's effectiveness for digital healthcare communication.

RESEARCH BACKGROUND

Smartwatches have revolutionized health monitoring by offering a range of advanced features tailored to diverse user needs [7]. Leading brands such as Apple, Samsung, and Fitbit [8] provide comprehensive health tracking capabilities, including heart rate monitoring [9], ECG functionality, blood oxygen measurement, and sleep tracking [10]. While these devices integrate seamlessly with their respective ecosystems and offer valuable health insights, they also come with certain limitations [11], such as device compatibility restrictions, reliance on proprietary apps, and the need for additional subscriptions for advanced features. This section explores the existing smartwatch solutions, their key functionalities, and their limitations to highlight areas for improvement in health monitoring technology.

2.1 Apple Watch

The Apple Watch is a premium smartwatch known for its comprehensive health monitoring capabilities, including heart rate tracking, ECG functionality, blood oxygen ($Sp0_2$) monitoring, sleep tracking, and fall detection. It integrates seamlessly with the Apple Health ecosystem, ensuring smooth data synchronization with apps. Additionally, it offers activity tracking, GPS navigation, and real-time notifications. However, its device exclusivity to Apple users and the requirement for subscription-based services for some advanced features limit its accessibility [12].

2.2 Samsung Galaxy Watch

The Samsung Galaxy Watch is a versatile health-tracking device compatible with both Android IOS platforms. It includes SpO_2 monitoring, ECG functionality, sleep tracking, and stress management tools. The watch integrates with Samsung Health and various third-party fitness apps, providing users with comprehensive health insights. Additional features such as activity tracking, GPS navigations, and smart notifications enhance user convenience. However, limited third-party app support and dependency on the Samsung Health app for advanced features may restrict user flexibility [13].

2.3 Fitbit Health Watches

Fitbit smartwatches prioritize health and wellness tracking, with models like the Sense 2 [14], Versa 4, Versa 3 [15], Charge 5, Inspire 3 [16], and Luxe offering continuous heart rate monitoring, ECG functionality, SpO_2 tracking, sleep analysis, and stress management tools. Fitbit devices integrate with the Fitbit app, which provides detailed health insights and API support for third-party applications. While Fitbit offers cost-effective options and a user-friendly experience, some models lack advanced health metrics, and smartphone dependence may limit standalone usability [17].

2.4 Why we Choose Fitbit Smartwatch?

Among the existing smartwatches, Fitbit was chosen due to its cost-effectiveness, comprehensive health tracking, and API support for seamless health data integration [18].

2.4.1 Fitbit Charge 5

Fitbit Charge 5 [19] was selected for its ECG functionality, SpO_2 tracking, stress management with EDA sensor, and built-in GPS, making it ideal for monitoring critical health metrics [20].

Figure 1: Fitbit Charge 5 [19]

2.4.2 Fitbit Versa 3

Fitbit Versa 3 [21] was chosen for its continuous heart rate monitoring and real-time API support, ensuring efficient real-time health data retrieval for continuous patient monitoring. Its advanced sensor technology enables accurate tracking of vital signs, supporting early detection of health anomalies.

***Figure 2: Fitbit Versa 3* [15]**

Research on Smart Rings for Health Monitoring Smart rings have emerged as compact health monitoring devices that provide continuous tracking of vital health metrics while ensuring user convenience. Some of the latest and most advanced smart rings include Oura Ring 4 [22], Samsung Galaxy Ring [23], Ultrahuman Ring Air [24], Amazfit Helio Ring [25], and Circular Ring Slim [26].

These rings primarily focus on heart rate monitoring, HRV (heart rate variability), sleep tracking, Spo2 (blood oxygen levels), body temperature, and stress monitoring. Each ring is designed with specific health and wellness goals, ranging from general fitness tracking to specialized metabolic health insights, such as glucose monitoring in the Ultrahuman Ring Air.

While smart rings offer several advantages, including compact design, 24/7 wear ability, and long batter life, that come with certain limitations. Their high cost, along with limited compatibility for advanced health metrics, makes them less accessible for immediate integration within the MediPulse project [27].

METHODOLOGY

3.1 Objective

The goal of MediPulse is to develop an integrated healthcare management system that integrates real-time monitoring of health parameters along with administrative and clinical functionality. The system is designed in a way to support continuous monitoring of the vital health parameters (e.g., heart rate, ECG, Sleeping Analysis and SpO_2) via wearable devices. Facilitate effective appointment scheduling and consultation management, both for physical and virtual sessions. Automate prescription generation and dispensing through direct interaction between doctors and pharmacies. Offer secure storage and transfer of data between modules via high-quality encryption and access control systems [28].

3.2 System Architecture

MediPulse designed as a web application operating over a multi-tier infrastructure of which comprises over several significant modules to support various stakeholders in the system. Following are the main stakeholders include in this:

i) Patient Portal: Supports registration, tracking of real-time health parameters, appointment scheduling, and examinations of previous medical history and reports [29].

ii) Doctor Dashboard: Offers a real-time patient health statistics, appointment scheduling of patients, and electronic prescription creation for seamless healthcare management system.

iii) Pharmacy Module: Processes and fills the digital prescriptions and manages the drug stock in the pharmacy. Administrative Interface Manages users, appointments, and analytics of the finest healthcare management system [30].

iv) Data Integration Layer: Connects with wearable devices (e.g., Fitbit Versa 3 and Charge 5) through their APIs to fetch and process health data continuously for improved monitoring.

Data gathered from smartwatches is transmitted securely to the backend server, and stored in an encrypted database, awaiting of the real-time analysis and decision-making [31].

3.3 Data Acquisition and Integration

Live health data capture is a key MediPulse Capability for providing instant and accurate patient data to physicians. The system gathers data from wearable wrist-watches like Fitbit Versa 3 and Charge 5 whose sensors are permanently under observation of the essential parameters like heart rate, ECG, Sleeping Analysis, and oxygen saturation. Unprocessed physiological data are transmitted securely over HTTPS to a server using encryption that ensures confidentiality and integrity in transit. The backend is based on NODE.JS, which gets and standardizes data in forms upon arrival and integrates it into patient profiles seamlessly. The backend, based on NODE.JS, gets and standardizes the data in standard form upon arrival, smoothly integrating it into patient profiles, Consequently, clinicians can have an end-to-end, real-time picture of patient health, supporting better-informed decision-making at the time of consultation and throughout care. By consoling, real-time health data seamlessly the system enables clinicians to gain a comprehensive, end to end view of patients well being for proactive health management throughout ongoing care of patients [32].

3.4 System Implementation

The system is developed through an integration of contemporary. Frontend is done using React.js [33] for web. Backend is done using NODE.JS (JavaScript) [34] due to the reasons of high-speed development, good security, and RESTful API [35] support. Patient information, appointment schedule and medication history are saved in an encrypted manner in a no-sql database (MONGODB) [36]. Transit and rest encryption, role-based authentication, and authorization scripts protect sensitive patient information, while secure APIs provide seamless integration with variable devices and third party integration such as payment gateways.

3.5 Operational Workflow

MediPulse's business process allows secure, real-time communication among stakeholders. Patient, physicians, and pharmacies, and bank office personnel all register and are authenticated through role-based, secure channels. Physiological measures [37] are continuously captured with wearable devices and securely communicated through HTTPS to a central server and processed, added to patient records for real-time clinical availability. Patient book appointments via the portal, while physicians view real-time information and patient histories on their dashboard. Electronic prescriptions created during the consultation are automatically routed to the pharmacy module, and all activities are safely logged and encrypted.

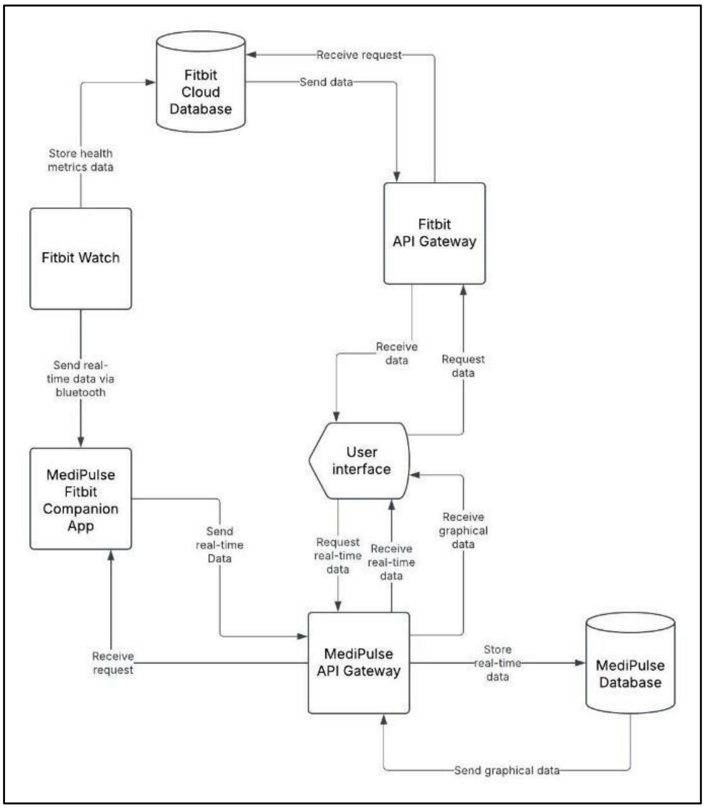

Figure 3: Operational Diagram of MediPulse

Figure 3 illustrates the integration of real-time health data between the Fitbit Watch and the MediPulse system. Health metrics collected by the Fitbit Watch are transmitted via Bluetooth to the MediPulse Companion App and forwarded to the MediPulse API Gateway for secure storage. The user interface enables real-time and graphical data visualization by retrieving records from the MediPulse database.

Predefined thresholds identify anomalies, sending immediate alerts to both patients and healthcare providers. A voice-to-text module powered by Whisper-large [38] transcribes doctor-patient dialogues into text with Mel spectrogram transformation [39], Transformer-based model [40], and beam search decoding [41], providing accurate, low-latency documentation. Data analytics module subsequently provide individualized health information and early intervention advice. For safe, efficient payments, the system accommodates multiple payment networks (e.g., Jazz Cash, Easy Paisa [42], eventual Stripe [43] integration) with payment data encrypted and end-to-end encryption and OTP role-based authentication to meet requirements like HIPAA [44].

3.6 Internal Architecture of Transcription

To transcribe and translate audio into Urdu (or other languages), the following steps are typically employed:

i) Automatic Speech Recognition (ASR): WhisperX first transcribes the input audio into text using Whisper's ASR capabilities. The model supports multilingual transcription, including Urdu, by leveraging its pre-trained multilingual checkpoints (e.g., large-v2).

ii) Forced Alignment: Unlike vanilla Whisper, WhisperX improves timestamp accuracy by aligning the transcribed text with the audio at the word level using forced alignment models (e.g., Wav2Vec2.0). This ensures precise synchronization between text and speech.

iii) Translation (Optional): If the input audio is in a non-English language, WhisperX can translate it into Urdu by enabling the task="translate" parameter during inference. The model generates translations directly from the source language to the target language (Urdu in this case).

iv) Batch Processing & Efficiency: WhisperX enhances processing speed through batch inference and optimized alignment, making it suitable for large-scale transcription/translation tasks.

In Figure 4, shows the visualization of transcription and translation of audio in Urdu and other languages [45].

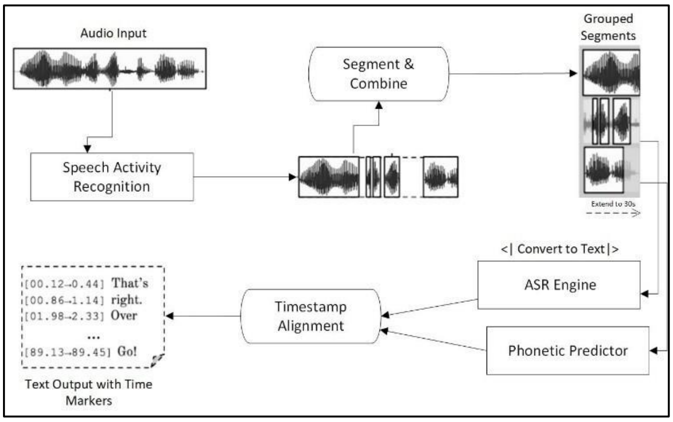

Figure 4: Internal Architecture of Transcription

3.7 Testing Accuracy of Transcription Module

In Figure 5, Record of experimental trials used to evaluate Urdu ASR performance, with word counts and timestamps documenting test consistency

Figure 5: Recent Tests

In Figure 6, Proportion of error types in Urdu speech recognition for Test #1, with substitutions accounting for 76% of the inaccuracies

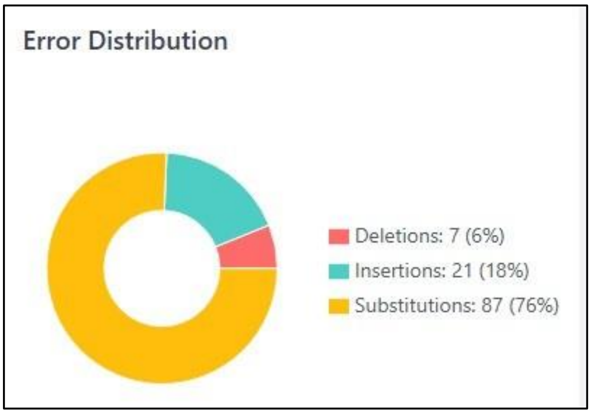

Figure 6: Error Distribution

In Figure 7, Radar chart comparing Urdu ASR performance metrics (Accuracy, Error Rate, Word Count, and No of Errors), highlighting the model's relative strengths and weaknesses across evaluation dimensions.

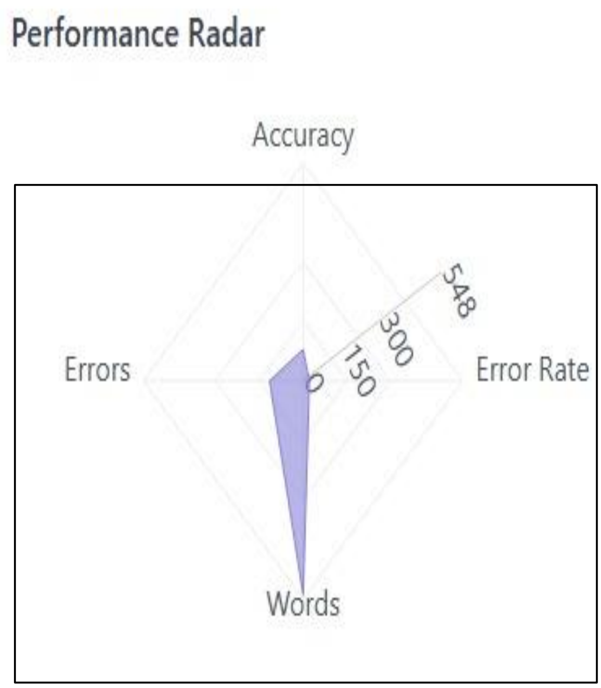

Figure 7: Performance Radar

In Figure 8, Summary of Urdu ASR evaluation results (May 23, 2025) showing 78.6% accuracy (WER: 21.4%) across 538 words, with error distribution dominated by substitutions (87/115 errors).

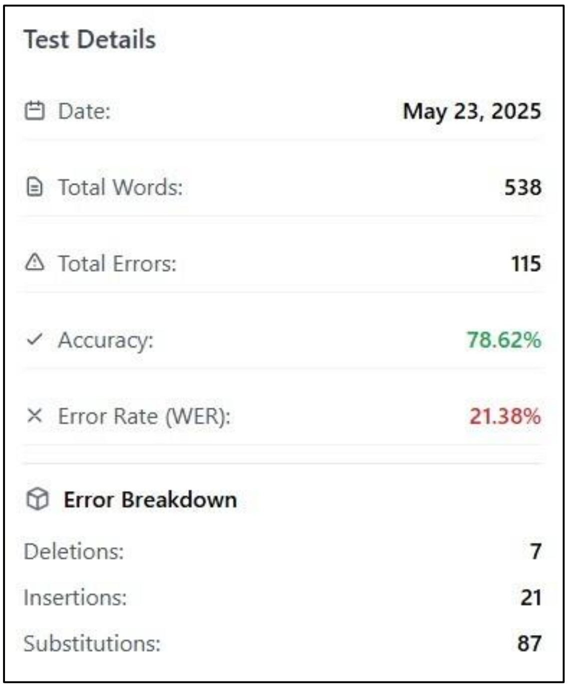

Figure 8: Test Details & Error Breakdown

The evaluation results from May 23, 2025 (Figure 8) demonstrate the Urdu ASR system's performance across 538 transcribed words, achieving an accuracy of 78.62% (WER: 21.38%). Error analysis revealed a pronounced dominance of substitution errors (87 instances, 75.7% of total errors), significantly outweighing insertions (21, 18.3%) and deletions (7, 6.1%). This distribution suggests phonetic or lexical mismatches as the primary challenge, potentially attributable to dialectal variations or limited training data for 18.3%) and deletions (7, 6.1%). This distribution suggests phonetic or lexical mismatches as the primary challenge, potentially attributable to dialectal variations or limited training data for specific Urdu phonemes. The low deletion rate (6.1%) indicates robust acoustic modeling, while insertions may stem from ambient noise or over-segmentation. These metrics establish a baseline for targeted improvements, particularly in reducing substitutions through context-aware language modeling or pronunciation lexicons [46].

3.7 Bar Plot for Overall Performance Averages

Figure 9, shows the overall performance averages for ASR (Automatic Speech Recognition) tests. It indicates:

I. *Accuracy:* The system transcribed 86.14% of speech correctly, as shown by the green bar.
II. *Error Rate:* The error rate is 13.86%, represented by the red bar, meaning 13.86% of transcriptions had errors.

These two metrics offer a clear visual comparison of performance: a relatively high accuracy rate and a moderate error rate. The data is accompanied by the count of 30 total tests included in this calculation.

Figure 9: Overall Performance Averages

RESULT

The MediPulse System offers a highly advanced and integrated solution for remote health monitoring and patient management, setting it apart from platforms like Oladoc and traditional healthcare providers such as Indus Hospital. Unlike Oladoc, which primarily serves as an online platform for appointment booking and doctor consultations, MediPulse goes a step further by integrating real-time health tracking through smartwatch sensors. These sensors continuously monitor vital signs such as ECG, heart rate, SpO_2, and sleep patterns, automatically syncing the data with the patient's mobile app — a feature not offered by Oladoc. While Indus Hospital provides high-quality medical care, it operates on a conventional in-person model, where vitals are recorded only during physical visits. This can lead to delays and limited access, especially for remote or chronically ill patients who require ongoing monitoring.

In contrast, MediPulse automates several key processes, including health data collection, report generation, appointment booking, and prescription delivery, creating a fully digital and patient-centric experience. Indus Hospital still relies heavily on manual systems for managing appointments and prescriptions, while Oladoc, although digitized, lacks integrated health monitoring and automated medical reporting features.

Moreover, digital prescriptions in MediPulse are sent directly to partnered pharmacies, significantly reducing prescription errors, a level of automation not fully achieved by either Oladoc or Indus Hospital. MediPulse also supports secure digital payments, minimizing reliance on cash transactions, whereas both Oladoc and Indus Hospital may still use manual or partially digitized payment methods.

Most importantly, MediPulse empowers doctors to access real-time patient data and provide timely, proactive interventions, marking a significant advancement over the static, visit-based diagnosis models used by both Oladoc and Indus Hospital.

CONCLUSION

The research findings clearly demonstrate that MediPulse offers a modern and efficient solution for remote healthcare monitoring. By integrating smartwatch technology, the system continuously tracks vital signs such as ECG, real-time heart rate, and SpO_2, and securely shares this data with doctors for timely and informed decision-making. The platform enables remote consultations where patient-doctor conversations are transcribed using advanced speech recognition, followed by precise word-level timestamp alignment. To ensure accessibility for diverse users, these transcriptions are translated into both Urdu and English using optimized translation mechanisms, enhancing understanding in native language contexts. MediPulse also delivers instant health alerts and digitally transfers prescriptions to pharmacies, streamlining the treatment process. In contrast, traditional hospitals like Indus Hospital depend on manual checkups and handwritten records, while platforms like Oladoc lack real-time vitals tracking and multilingual transcription. MediPulse bridges these gaps by enabling continuous monitoring, accurate and accessible communication, and data-driven care, making healthcare more inclusive, timely, and patient-focused.

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