Role-Based Secure Telehealth in IoMT Ecosystems: Design Insights from NeuroPredict Platform

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Abstract: This paper presents NeuroPredict, a modular cloud–edge platform designed for secure and scalable telehealth monitoring of the neurodegenerative diseases such as Alzheimer's disease (AD), Parkinson's disease (PD), and Multiple Sclerosis (MS), with a focus on the implemented security measures. The platform integrates IoMT devices, validated clinical questionnaires, and role-specific dashboards for patients, caregivers, and physicians. Its novelty lies in a multi-layered security framework that incorporates advanced encryption, token-based authentication, and dynamic session keys. This approach utilizes short-lived credentials to mitigate the risks of replay and hijacking attacks. The role-based access control enforces the least-privileged authorization. By combining hybrid edge-cloud analytics with strong security and usability, the NeuroPredict platform advances IoMT-based monitoring for the management of the neurodegenerative diseases.
Keywords: Telehealth, Cloud–Edge Architecture, Internet of Medical Things (IoMT), Security, Neurodegenerative Diseases, Monitoring; Role-Based Access Control (RBAC)

INTRODUCTION

Among the most significant medical concerns of the twenty-first century are the neurodegenerative diseases, such as multiple sclerosis (MS), Parkinson's disease (PD), and Alzheimer's disease (AD). They are associated with progressive decline in cognitive and motor functions, resulting in loss of autonomy, long-term dependence on caregivers, and increasing strain on healthcare systems (Shaik et al., 2025; De Marchi et al., 2021). The impact of these diseases extends beyond patients. Caregivers of individuals with AD, PD, and MS consistently experience considerable strain, with evidence of substantial psychological distress, reduced quality of life, and negative health outcomes among care partners (Kelley et al., 2025; Aamodt et al., 2024).

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The need for safe, patient-centered monitoring solutions has been emphasized by the knowledge that AD, PD, and MS dramatically increase the worldwide prevalence of neurological disorders, according to global analyses (GBD 2021 Nervous System Disorders Collaborators, 2024; WHO, 2024). Episodic clinical visits are the backbone of the traditional monitoring, which fails to notice subtle or quick changes, reducing the opportunities for timely interventions. The gap is filled by the continuous IoMT-based monitoring, which uses wearable and embedded sensors to collect physiological, behavioural, and environmental data. When combined with AI-driven analytics, this approach enables early diagnosis and proactive and personalized care.

Telemedicine targets modifiable risk factors provides access to healthcare, and allows data collection at home. Long-term validation is necessary, but cognitive-behavioural therapy administered through telehealth also shows promise in reducing anxiety and depression in PD patients (Swalwell et al., 2018). Despite these developments, challenges remain. IoMT systems are still vulnerable to hacker attacks and illegal access, so maintaining trust requires compliance with the EU Artificial Intelligence Law and the GDPR. Because it involves numerous stakeholders with distinct requirements, the role-based access control (RBAC) is proving important for privacy and collaboration (Ali et al., 2024; Calvillo-Arbizu et al., 2019). Adaptive dashboards and user-friendly interfaces are important in this regard.

To directly address these needs, the NeuroPredict platform, a secure telehealth model for monitoring the neurodegenerative diseases (AD, PD, and MS), integrates technological innovation with user-centered design and regulatory compliance (Ianculescu et al., 2025). It has been developed as a multi-layered, modular solution that combines cognitive assessment tools with both commercial and custom IoMT devices, employs Time-Generated Authentication Keys (TGAK), Transport Layer Security (TLS), and Open Authorization (OAuth) 2.0 to ensure security, and provides dashboards tailored for patients, caregivers, and physicians (Bica et al., 2024).

The NeuroPredict platform is presented in this paper along with its role-based dashboards designed to enhance usability, protect privacy, and support clinical decision-making, its layered cloud-edge architecture for IoMT-based multimodal monitoring. and its end-to-end security framework that uses TLS, OAuth 2.0, and TGAK to boost usability, protect privacy, and support clinical decision-making.

RELATED WORK

Current research highlights that IoMT can enable the continuous monitoring of patients with neurodegenerative diseases. Predictive models for early diagnosis and individualized care are made possible by wearable and embedded devices' ability to collect multimodal data (e.g., biometric and environmental parameters, accelerometer-based gait patterns) (Powers et al., 2021; Salvi, Garg & Gurupur, 2025). For example, a smartwatch-based system, Mobile Monitoring of Movement in Parkinson's Disease (MM4PD), has been developed (Powers et al., 2021). Similarly, the Instrumental Activities of Daily Living System (IADLSys), an Internet of Things (IoT)-based multimodal platform that integrates wearables, wireless tags, and cloud analytics to monitor activities of daily living in AD patients, has been introduced (Salvi et al., 2025). These studies demonstrate the substantial potential for enhancing diagnostic sensitivity and encouraging proactive interventions through the use of AI with IoMT.

The adoption of the IoMT-based health platforms requires strong security and privacy protection, in addition to ensuring data availability. For resource-constrained devices, lightweight authentication models that strike a balance between efficiency and robustness have been proposed (Ali et al., 2024). Meanwhile, the importance of user-centered design in ensuring adherence and usability, particularly for older adults, has been emphasized (Calvillo-Arbizu et al., 2019). Another challenge is preserving consistency and trust in opportunistic, distributed, and mobile environments. Drop Computing, a framework that offers mechanisms to avoid data corruption and ensure consistency in decentralized healthcare scenarios, has been introduced to address this issue (Ciobanu et al., 2019). These methods draw focus to different paradigms that can be used in combination with the conventional cloud-edge architectures, particularly when the connectivity is inconsistent.

Large-scale pilot projects have validated the potential of IoMT, confirming user satisfaction and acceptance. Projects such as vINCI have demonstrated how smart devices such as depth cameras and insoles can be combined with quality-of-life assessments to support assisted living (Băjenaru et al., 2018; Bajenaru et al., 2022). In accordance with the cloud–edge paradigm used in NeuroPredict, complementary efforts have presented scalable IoMT architectures with secure communication protocols (Vădan and Miclea, 2024).

Initiatives such as MyHealthMyData (MHMD) (European Commission, Horizon 2020, 2017–2020) and REACT (European Commission, MSCA, 2022–2025) have promoted safe health data sharing and AI-powered care coordination in distributed healthcare environments at the European level. The granular integration of edge intelligence and multimodal IoMT sensing is the way NeuroPredict sets itself distinct from these projects, which emphasize federated interoperability and privacy-preserving analytics. In contrast to REACT's emphasis on hospital-level orchestration and MHMD's blockchain-based trust framework, NeuroPredict employs embedded edge gateways (such as the Raspberry Pi and ESP8266) and the national ICIPRO cloud to facilitate TGAK-managed communication and real-time, AES-encrypted data processing in both clinical and home settings.

SYSTEM ARCHITECTURE OF THE NEUROPREDICT PLATFORM

Layered Architecture Overview

The NeuroPredict platform employs a five-layered architectural approach to managing tele-health medical data which enhances security and flexibility, while still robust and stable. It allows for the real-time and continuous automated tracking and monitoring of the patients suffering from various neurodegenerative disorders, while providing real-time local processing and strong protective measures for sensitive data (Băjenaru et al., 2024; Ianculescu et al., 2025). The architecture of the NeuroPredict platform is presented in Figure 1.

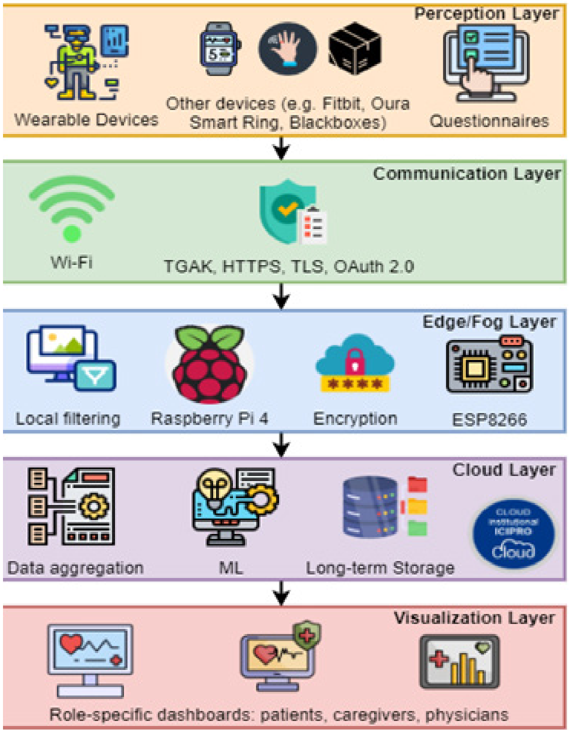

Figure 1. *Layered architecture of the NeuroPredict Platform*

The perception layer integrates on commercial IoMT devices such as Withings (2025), Fitbit (n.d.), Oura (Oura Health Oy, 2025), and CareSens (Spirit Health, 2024), and proprietary modules such as the Medical Blackbox, Ambiental Blackbox, and Gaitband to capture multimodal signals. The data is transported through the communication layer by TGAK, and HTTPS with OAuth 2.0, and processed at the edge/fog level (Raspberry Pi, ESP8266) for filtering, encryption, and local decision support.

Aggregation, ML, and compliance-grade storage occur in the cloud layer, and the patient dashboards, caregiver dashboards, and physician dashboards can be viewed in the visualization layer.

Each layer has a specific role, from data capture at the sensor level through analytics in the cloud to personalized dashboards. Easy integration of IoMT devices, secure communications, and efficient filtering of clinically relevant signals are also part of the architecture. The system's isolation of sensing, processing, and visualization makes it easier to add new devices or user roles, is more robust, and less complex to upgrade. Security is embedded from the outset through TGAK, OAuth 2.0 authentication, and TLS encryption for confidentiality and access control. This multi-layered architecture evolves from device-focused monitoring to patient-focused care, harmonizing edge and cloud capabilities within a flexible and scalable telehealth platform. The Perception Layer captures signals (cognitive, behavioural, and physiological variables). These are sent through HTTPS over Wi-Fi to the Communication Layer. Local buffering, encryption, and filtering, with medical modules using Raspberry Pi and ESP8266 gateways, are dealt with by the Edge/Fog Layer. The Visualization Layer provides dashboards to patients, caregivers, and physicians.

The Perception Layer: The IoMT Ecosystem

The Perception Layer is the foundation of NeuroPredict, dedicated to the continuous acquisition of heterogeneous patient data through a wide ecosystem of IoMT devices. It collects physiological, cognitive, and behavioural signals essential for tracking the targeted neurodegenerative diseases. Also, this layer integrates a large spectrum of IoMT devices for multimodal monitoring. Commercial wearables include the Withings BPM Core (blood pressure, pulse, ECG), Withings Body Scan (weight, body composition, nerve activity, cardiovascular and metabolic biomarkers), Withings Sleep Analyzer (sleep quality and respiratory parameters), Fitbit Charge 5 (activity tracking, heart rate, SpO_2), and the Oura Ring (sleep, stress, and recovery) (Oura Health Oy, 2025).

The medical devices are represented by the CareSens Glucometer for blood glucose monitoring. In addition, proprietary modules expand the coverage: the Gaitband captures triaxial accelerometry, posture, and GPS location; the Medical Blackbox collects ECG, SpO_2, body temperature, breath CO_2, alcohol concentration, and urinary biomarkers; while the Ambiental Blackbox monitors environmental conditions such as temperature, humidity, air quality, gas/fume detection, and atmospheric pressure. Together, these sensors provide a multidimensional view of the cardiovascular, metabolic, neurological, and behavioural health. All devices connect wirelessly via Bluetooth and/or Wi-Fi and are automatically registered at the edge gateways. This configuration is enhanced by proprietary in-house developed modules: Gaitband (accelerometry, gyroscope-based posture, GPS), Ambiental Blackbox (for ambient temperature, humidity, gases, pressure, and air quality), and Medical Blackbox (ECG, SpO_2, temperature, breath CO_2 and alcohol, and urine biomarkers). The platform features evidence-based questionnaires that have been clinically tested for the functional, cognitive, affective, and neuropsychiatric domains. The Patient Health Questionnaire (PHQ-9) is a validated measure used to rate the depressive symptom severity (APA, n.d.). Comparable, valid instruments are also used to assess functional status, fatigue, and behavioral symptoms. The perception layer enables the detection of gait abnormalities, arrhythmias, and apnea; periodic readings of blood pressure and glucose; and continuous data capture of heart rate and movement.

The Communication Layer

The Communication Layer connects the Perception Layer with the Edge/Fog and Cloud components, enabling a secure data transfer in uncertain home or clinical networks. It is a three-tiered communication stack-based solution. With secure pairing and reconnection by default, Wi-Fi enables the high-bandwidth, short-distance transmission from wearables like the Fitbit Charge 5, Body Scan, and Withings Sleep Analyzer to local gateways. Through OAuth 2.0 and token-based access control, HTTPS (TLS 1.3) encrypts traffic to the cloud through REST APIs. Besides authentication, to prevent unauthorized usage, the platform uses TGAK.

Unlike static credentials, TGAKs are generated dynamically and possess a lifespan within defined windows of time, thus reducing the risk of exposure in case of interception. With token-based REST access and TLS encryption, TGAK ensures session-level integrity through associating access with time windows, thus constraining interception threats in edge–cloud communications.

The Edge/ Fog Layer

With local intelligence close to the source, the Edge/Fog Layer reduces latency, bandwidth consumption, and privacy threats through guaranteed intermediate processing between sensor data collection and cloud processing. Drawn on ESP8266 microcontrollers and Raspberry Pi 4/Zero W boards, the layer pre-processes data, makes decisions, and securely packages before sending. The basic operations include anomaly detection, temporal synchronization of multiple devices' streams, signal denoising (such as ECG, gait), and feature extraction to decrease data dimensionality. The performance of the downstream ML models is enhanced by the early-stage analytics that guarantee clinically meaningful filtered data end up in the cloud.

The previous research on task scheduling strategies in edge–cloud environments has identified the limitations of the conventional task scheduling methods (Stan et al., 2021). This highlights the need for NeuroPredict's optimized edge pipelines to be resilient under constrained resource situations. Security is supported by AES-256 encryption, SHA-2 hashing, and TGAK, providing confidentiality and integrity in transit. The Edge/Fog Layer is integrated with the NeuroPredict's hardware devices, including the Gaitband, Ambient Blackbox, and Medical Blackbox. These devices provide the gateway integration for secure data acquisition, validation, and dispatch. For emergency conditions (e.g., hypertension or abnormal gait), local alerts enable real-time feedback to patients before cloud validation.

The Cloud Layer

The Cloud Layer gathers, processes, and stores multimodal data from the edge nodes and IoMT devices, and is the computational and storage foundation of the NeuroPredict. The software runs on the ICIPRO national cloud. It also enables the deployment of the modular ML and AI services, with access to the sensitive data remaining. Retrospective studies and live clinical guidance are both enabled. The data entering the cloud are not only stored but tagged, normalized, and synchronized across sources: gait signals, blood glucose levels, or EKGs. As a result, the longitudinal patient profiles encompassing behavioural, cognitive, physiological, and environmental parameters can be constructed. The architecture can integrate event-based updates (in addition to the continuous stream data). The ML systems are applied to detect anomalies, forecast trends, the cognitive score, and perform multivariate risk profiling. With filtered data centralization, the Cloud Layer transforms the NeuroPredict into an AI-driven health platform enabling proactive decision making and remote monitoring of the neurodegenerative diseases.

The Visualization Layer with Role-Based Dashboards

The Visualization Layer connects users with backend analytics by converting complex data into role-specific dashboards. The dashboards are maintained safely, accessible, and responsive with TLS-encrypted HTTPS, OAuth 2.0 authentication, and time-based token renewal. RBAC makes sure that users only view the content that is relevant to their roles.

Patients receive simplified views that include visual trends (heart rate, sleep, activity, and stress), daily health summaries, assessment feedback, alerts for anomalies, and gamified features that encourage adherence. The vital status, problems with sleep, environmental risks (temperature, air quality), and critical events (e.g., inactivity, high CO_2, or alcohol levels) are a few aggregated indicators and real-time alerts that the caregivers can access. To support diagnosis, monitoring, and treatment planning, researchers and physicians can use dashboards for multimodal signal visualization, ML-based risk assessment, anomaly indicators, and cognitive scores. NeuroPredict uses end-to-end encryption at every layer with TLS 1.3 for secure communications, AES-256 for data confidentiality, and SHA-2 hashing for message integrity. When combined with the TGAK-based session management and RBAC, these security measures ensure privacy, authenticity, and protection from online attacks via the internet. All things considered, the Visualization Layer transforms NeuroPredict into a collaborative, decision-focused telehealth setting by promoting evidence-based decisions, increasing caregiver support, and improving patient engagement.

Multimodal Data Acquisition and Processing Enhancements

Building on the multi-layer architecture described in Section 3.1, the NeuroPredict platform also includes other novel multimodal and clinically related data acquisition enhancements.

Besides the above-mentioned layered architecture, NeuroPredict utilizes several innovative data modalities that enhance its clinical value. Besides biometric signals, the system tracks the behaviour and motor-related indicators such as number of steps, symmetry of steps, gait cadence, and plantar pressure distribution that are significantly correlated with the progression of the neurodegenerative disease and fall risk (Rancea, Anghel & Cioara, 2024). Second, the system includes gamified cognitive assessment tests embedded within the interface. The interactive, light-weight probes regularly test the executive function, memory, and attention, complementing standardized questionnaires with ecologically valid, real-time measures of cognition. The feasibility of this multimodal strategy is supported by the results from the vINCI project, which demonstrated the benefits of combining wearable sensors with validated questionnaires for a comprehensive digital profiling of older adults (Băjenaru et al., 2022; Dobre et al., 2023). By extending the traditional assessments into daily life, NeuroPredict strengthens the ecological validity of the telehealth monitoring and enhances its potential for proactive care. Figure 2 shows how the additional behavioural, motor, and gamified cognitive data are integrated into the pipeline and visualized through differentiated dashboards.

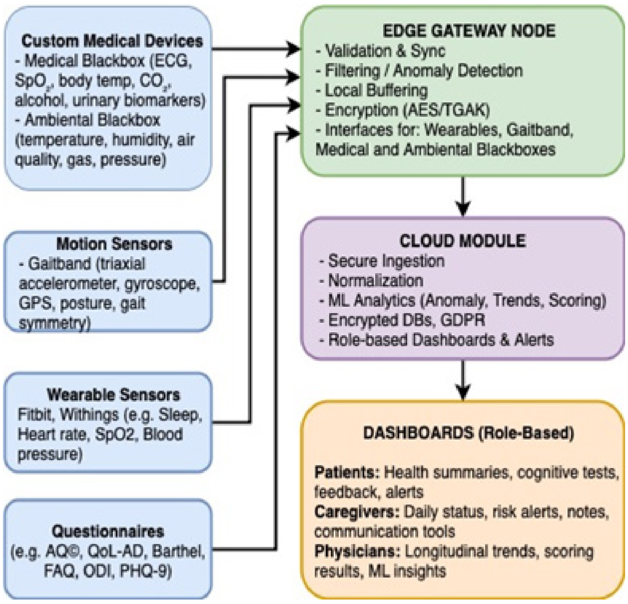

Figure 2. *Data flow across IoMT, cloud, and dashboards in the NeuroPredict platform*

Authentication and Session Management

The previous work, such as the RO-SmartAgeing system (Ianculescu et al., 2020), demonstrated the importance of securing medical data through OAuth 2.0 tokens with periodic refresh mechanisms (Nicolau et al., 2023). Using this framework, the NeuroPredict platform integrates OAuth 2.0 with TGAK to make sure that the token-based security and session-level integrity are maintained in dispersed edge-cloud workflows (Bica et al., 2024). A session security construct, TGAK, was designed to extend OAuth 2.0 with time-bound, cryptographically generated credentials. By generating ephemeral keys at the edge gateway and the cloud backend with a life of just a few minutes (e.g., 60–120 seconds), TGAK establishes a temporal session binding. The user role, nonce, timestamp, and device ID are utilized for generating these keys, which are invalidated and rotated dynamically in the event of logout or session refresh. Both the OAuth access token and the corresponding TGAK need to be presented by the clients during API calls. To avoid misuse of the intercepted tokens outside their valid duration window, the server verifies both credentials. With low overhead for the IoMT devices and maintaining low exposure and responsibility, GDPR-compliant, the multi-layered approach significantly reduces the exposure to hijack or replay attacks.

By providing short-lived access tokens with refresh tokens for controlled renewal, OAuth 2.0 defines the standard for user and device authentication. NeuroPredict uses OpenID Connect (OIDC) to provide verified identity attributes and the Authorization Code flow with Proof Key for Code Exchange (PKCE) to ensure that intercepted codes cannot be reused for interactive users (patients, caregivers, and doctors). On the other hand, the headless IoMT devices rely on the Client Credentials flow for backend-to-backend communication and the Device Authorization Grant for onboarding, both of which are limited by role-specific scopes. Figure 3 presents the standard OAuth 2.0 authorization code flow with PKCE and OIDC. This shows core exchanges between the Resource Owner, Client, Authorization Server, and Resource Server. This standard workflow provides the baseline upon which NeuroPredict adds TGAK for a stronger, time-bound session security.

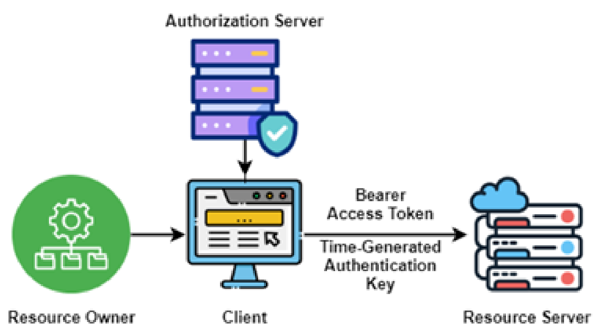

Figure 3. *Standard OAuth 2.0 Authorization Workflow*

The following steps present an overview of the authorization workflow:

- The **Resource Owner** (patient, caregiver, or physician) makes a request via the client (such as an online dashboard) to obtain protected health data.
- The **Client** uses the Authorization Code flow with PKCE to send an Authorization Request to the Authorization Server.
- The **Authorization Server** gathers the permission, authenticates the user through OIDC, and provides the client with an authorization code.
- The **Client** trades the PKCE verifier and the authorization code for a refresh token (with rotation and reuse detection) and a temporary access token.
- The **Client** uses the Bearer access token in the request header to call the Resource Server (API Gateway).
- The **Resource Server** returns the requested protected resource after validating the token. It performs a token introspection as required. The token revocation immediately flows across OAuth and TGAK upon logout; the client utilizes the refresh token to request a new one when the access token expires.

ROLE-BASED ACCESS CONTROL AND ADDITIONAL SECURITY MECHANISMS

The secure and reliable access-control measures represent a major concern when designing and implementing the remote health-monitoring platforms, especially when integrating data from distributed IoMT devices, as sensitive data should be protected at each layer: device, network, application, and storage.

Role-Based Authentication and Authorization

The platform implements a role-based authorization scheme for controlling the access to resources. Access rules are enforced at both the application and database layers through a policy-driven middleware that evaluates user identity, assigned role, and the context of the request (e.g. IP address, session). This approach guarantees that each user interacts only with data relevant to its clinical responsibilities. The principle of least privilege is enforced when required: for each implemented functionality, each role receives access only to the minimal required dataset.

The front page of the web application is presented in Figure 4. Unauthenticated users have access to limited functionalities: the contact form and a preliminary risk assessment of an individual's ability to live independently.

The authentication, authorization, and auditing workflow is presented in Figure 5. All login attempts are logged. After a successful login, the user is redirected to a role-specific landing page. Any access to or modification of sensitive data is captured in the audit log to ensure traceability and non-repudiation.

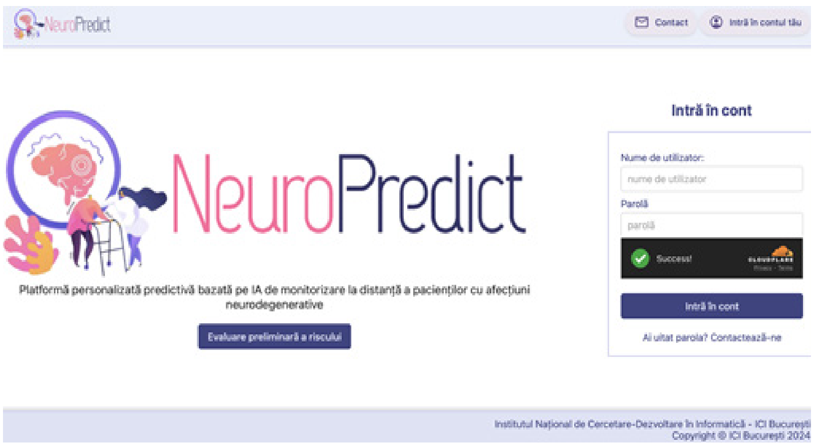

Figure 4. *Front page of the NeuroPredict platform*

All role-based actions that involve key sensitive data are monitored through audit logs that record user identity, access time, and data interaction type. The django-audit-log-middleware module (Community contributors, 2024), based on the python-ipware module (Val Neekman, 2024), is integrated for this purpose. The caught requests are filtered so that only relevant interactions are recorded.

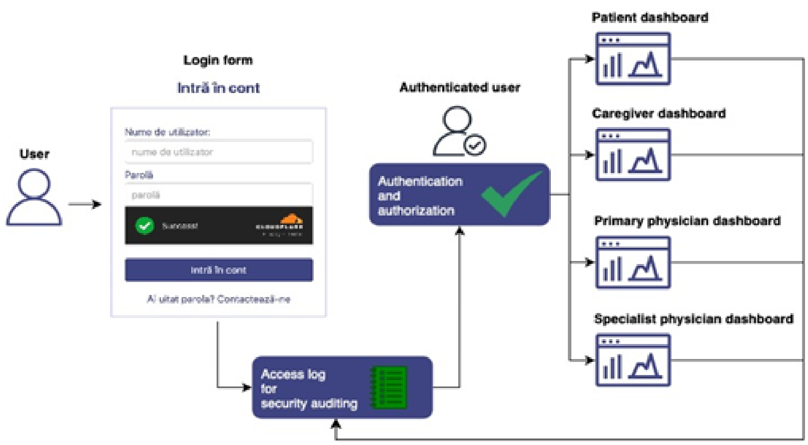

Figure 5. *Authentication, authorization, and auditing flowchart*

The following user categories are defined:

- ***Patients:*** Patients log into the platform using personalized credentials linked to their unique patient identifiers. They are granted access exclusively to their personal health records, including sensor data collected from IoMT devices, results of the self-administered cognitive and functional questionnaires and personalized feedback modules. The functionalities available to patients promote patient empowerment and engagement, and the role-based mechanism prevents cross-patient data exposure.
- ***Caregivers:*** The caregivers, both formal (medical staff) and informal (family members), are authorized with a restricted view to alerts, daily monitoring streams, and summary dashboards highlighting medical recommendations, alerts, and unread and recent messages. Their access does not extend to the predictive scores or diagnostic classifications. The medical recommendations are subject to a physician's approval. The caregiver view emphasizes timely interventions and the adherence to daily routines, thereby reducing the burden on physicians while safeguarding sensitive medical interpretations.
- ***Physicians:*** Physicians are granted the most extensive access privileges. Their clinical dashboard integrates longitudinal data from IoMT devices, structured outputs from questionnaires, cognitive games, an electronic patient-reported symptoms log, and AI-driven predictions of the disease status and progression. This comprehensive view supports the clinical decision-making and personalized treatment planning, while the access controls ensure that such sensitive data are only disclosed to authorized roles. Only a physician has the full picture for the patients who are completely under his direct medical care.
- ***Medical specialists:*** Each patient has a primary physician (detailed above) who completely manages the medical data of the patient and who may assign other medical specialists to interact with the patient and collaborate. Medical specialists are physicians with full read access rights to assigned patients' data but with restricted action permissions (e.g., may upload medical reports, as a visit record, may recommend tests and medication – to be approved by the primary physician, but may not delete sensitive data).

Additional Security Measures

Additional security measurements are implemented according to the standard best practices recommended for web-based applications, in general, and specifically for the Django projects (Django Software Foundation, 2025).

- ***Encrypted Data Transmission over HTTPS*** - Within the NeuroPredict platform, TLS is reinforced through policies that constrain traffic to be exclusively sent on encrypted connections and prevent access via insecure channels. All communication between client and server, on domains and subdomains, is constrained to HTTPS only. The platform is set to instruct browsers on this requirement from the first interaction using preloaded safety lists. An additional security setting enforces that the information transmitted to external domains via the referrer header is restricted to the base address only, excluding additional details or parameters that might expose sensitive data. As a result, the risk of data interception, downgrade attacks, and accidental data leakage is reduced. This ensures a high level of confidentiality and integrity across remote health monitoring sessions.
- ***Human vs. bot verification*** - The NeuroPredict platform uses Cloudflare Turnstile (Benedikt Wolters, Maxime Guerreiro & Adam Martinetti, 2023) as a privacy-preserving, user-friendly alternative to traditional CAPTCHAs (Completely Automated Public Turing test to Tell Computers and Humans Apart). CAPTCHAs are meant to distinguish

between actions performed by human users and bots. Studies show that traditional CAPTCHAs (text recognition captchas, image picking, etc.) are solved with better accuracy by bots (Searles et al., 2023), sometimes leading to user disengagement (Bock et al., 2017) and causing accessibility issues, as it is shown that older adults and people with different disabilities solve them more slowly or cannot solve them (Searles et al., 2023). Turnstile, the solution chosen for NeuroPredict, replaces user-friction puzzles with non-interactive, risk-based checks that run in the browser. It evaluates signals and performs lightweight, privacy-respecting challenges to decide whether the visitor is likely human. It relies on session data and performs passive (non-user interactive) in-browser tests (e.g., proof-of-work, proof-of-space tests) (Benedikt Wolters, Maxime Guerreiro & Adam Martinetti, 2023). NeuroPredict integrates Turnstile on the login page (interactively after a predetermined number of failed login attempts), on the reset password pages, and when changes in the session data are detected, balancing usability and security by challenging only under elevated risk.

- ***Limited login attempts*** - Login attempts in a defined time frame for an IP address or username are limited to prevent brute-force attacks. The django-axes module (Community contributors, 2025) is integrated both at the middleware and the backend layers. It intercepts login attempts and stores them for analysis and enforcement of security policies. Specifically, django-axes maintains counters of failed authentication events keyed by parameters such as username and IP address. When the configured threshold of failed attempts within a given time window is exceeded, further login attempts are automatically blocked, thereby mitigating brute-force attacks. In addition to enforcing lockout policies, the django-axes provides configurable storage backends, whitelisting mechanisms for trusted networks, and detailed logging options for audit capabilities that facilitate forensic analysis of the authentication events. Its integration both as middleware and as an authentication backend has a minimal impact on the existing application logic while protecting against brute-force and credential stuffing attacks. The NeuroPredict platform blocks both the user account and IP address after the predefined number of failed attempts for a customizable time frame. The user/ IP address may be unblocked by a system administrator on request.
- ***Session Cookie Security*** - Session management within NeuroPredict is reinforced by configuring cookies to be transmitted exclusively over encrypted channels and inaccessible to client-side scripts (Django Software Foundation, 2025). By marking cookies as Secure and HTTPOnly and applying SameSite policies, the risk of theft through cross-site scripting or misuse in cross-site contexts is substantially reduced. These measures strengthen the integrity of the user sessions and limit the attack surface for session hijacking in telehealth workflows.
- ***Cross-Site Request Forgery Protection*** - To prevent unauthorized actions triggered from external domains, the platform enforces cross-site request forgery protection. CSRF tokens are validated against a trusted origin list, ensuring that requests originate only from legitimate sources. This mechanism mitigates cross-site request forgery attacks, safeguarding sensitive operations performed through input forms, such as login, patient data updates, and messaging.
- ***Content Security Policy Enforcement*** - The system employs a restrictive Content Security Policy (CSP) (World Wide Web Consortium, 2025) to control the execution of scripts, the inclusion of styles, and the embedding of external frames. Only explicitly authorized domains are permitted to load executable content, which significantly reduces the likelihood of

cross-site scripting and clickjacking attacks. Custom assets (e.g., fonts) are stored locally, so that their content is verified and the risk of an attacker replacing the public URL, e.g. on a public Content Delivery Network (CDN), with malicious content is mitigated. By limiting the sources of active content, CSP provides an additional protective layer that complements the authentication and session safeguards, enhancing the overall resilience against web-based exploits.

CONCLUSIONS

The modular cloud-edge telehealth platform NeuroPredict, developed for continuous neurodegenerative disease monitoring, is presented. By combining validated questionnaires, gamified cognitive tasks, and both proprietary and commercial IoMT devices, it enables multimodal patient profiling that goes beyond the conventional episodic assessments. Its distinctive feature is reflected in a multi-layered security framework that ensures privacy, session integrity, and clinical relevance through the integration of TLS-encrypted communication, OAuth 2.0, TGAK, and RBAC-based dashboards. Under GDPR compliance, the hybrid edge-cloud architecture facilitates scalable AI-driven analytics, local decision support, and real-time anomaly detection. Verified through laboratory simulations, the NeuroPredict platform demonstrates the feasibility of a safe, scalable, and patient-centered telehealth solution. The platform is still under development, with upcoming work aimed at extending the pilot evaluations and refining both security and usability aspects. Future work involves clinical validation in collaboration with partner hospitals, focusing on Alzheimer's and Parkinson's cohorts. The evaluation will assess data reliability, model accuracy, and user adherence in real-world telehealth scenarios.

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