Brief Report

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Real-Time Remote Patient Monitoring in Mountainous Regions: Architecture and Pilot Deployment of a Telemedicine Ecosystem

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Real-Time Remote Patient Monitoring in Mountainous Regions: Architecture and Pilot Deployment of a Telemedicine Ecosystem

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Abstract

The rugged morphology and dispersed settlements of the Calabrian region pose long-standing barriers to timely and equitable access to healthcare, particularly for elderly and fragile populations living in mountainous areas. In this paper, we present a telemedicine ecosystem specifically designed for Calabria that integrates certified wearable wristbands, secure communication infrastructure, and intelligent back-end services to enable continuous home monitoring and rapid clinical intervention. Building on the SidlyCare platform, the system acquires real-time physiological signals (heart rate and oxygen saturation), streams them to a central server through encrypted channels, and applies machine learning and deep learning-based anomaly detection models to identify both acute and insidious deteriorations in patient status. Alerts are propagated via a multi-stakeholder workflow involving patients, family caregivers, general practitioners, non-profit organizations, and local health authorities, who interact with the platform through role-specific dashboards that support longitudinal visualization, risk stratification, and integration with existing electronic health record infrastructures. A pilot case study in a tele-home care programme for elderly patients in Calabria demonstrates the feasibility and potential of this architecture to improve safety, foster patient engagement, and strengthen continuity of care in geographically isolated communities, offering a scalable blueprint for territorial telemedicine in similar rural and mountainous contexts.

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1. Introduction

Implementing telemedicine in the Calabrian region of Italy constitutes a transformative approach aimed at overcoming significant geographical obstacles, enhancing the provision of healthcare services, and ultimately elevating the quality of life for populations residing in its mountainous territories. The inherently rugged terrain combined with a widely dispersed population has historically impeded timely and equitable access to medical care. To address these challenges, a telemedicine platform specifically customized for Calabria has been developed, harnessing cutting-edge digital health technologies to connect patients and healthcare providers more efficiently [1,2].

Telemedicine assumes a crucial role in regions such as Calabria, where physical barriers considerably restrict the accessibility of healthcare infrastructure. By facilitating remote medical consultations, continuous monitoring of patient health, and the delivery of prompt medical guidance, telemedicine can substantially enhance clinical outcomes [3,4]. The integration of telemedicine solutions transcends mere logistical convenience; it also optimizes healthcare operational efficiency, underpinning modern healthcare frameworks in geographically isolated and underserved areas [5,6].

A key innovation in the Calabrian telemedicine system is the deployment of advanced wearable technologies such as wristbands, which allow for real-time collection and transmission of vital physiological data, including heart rate, blood pressure, and oxygen saturation [7–9]. These devices empower patients to actively participate in their personal health management and provide clinicians with continuous data streams for early detection of adverse events and more proactive intervention. The use of wristbands and similar wearables has also demonstrated utility in other telemedicine projects for mountainous regions, providing reliable, non-invasive monitoring even in remote or rugged environments [6,10,11].

The Italian Integrated Home Care (IHC) model exemplifies the broader national effort to standardize and extend telemedicine across diverse, sometimes hard-to-reach, territories. Through interoperability frameworks, electronic health records, and centralized digital portals, telemedicine connects patients and providers irrespective of geographic barriers, facilitating delivery of care that is both timely and comprehensive [2]. Similar approaches are now being replicated at a continental scale, reinforcing the role of telehealth in territorial medicine, chronic disease management, and emergency remote consultation [5,6,8].

Challenges remain, notably regarding digital infrastructure in rural territories, connectivity, data privacy, and the equitable distribution of technological resources [9,12]. Nonetheless, the deployment of telemedicine coupled with wearable health monitors is increasingly viewed as a cornerstone of healthcare innovation for mountainous and rural populations [10].

In summary, the ongoing expansion and refinement of telemedicine in Calabria and across Italy's mountain regions highlight how digital health initiatives can dismantle barriers, optimize care delivery, and add resilience to health systems facing the unique challenges of geographical isolation. With continual investment, research, and the integration of advanced wearable technologies, such models pave the way for accessible, effective healthcare in even the most remote communities.

Paper is structured as follows: Section 2 discusses the related work, Section 3 presents the proposed architecture, Section 4 outlines a case study, finally Section 5 concludes the paper.

2. Related Work

Italy's heterogeneous geography and longstanding regional disparities have led to significant investment in digital health infrastructure and telemedicine networks [13,14]. National programmes have strengthened both public awareness and the regulatory foundations of telemedicine, advancing standardization and widening access to digital care pathways [15,16]. Wearable medical technologies now form a central pillar of remote monitoring, enabling continuous assessment of physiological parameters and prompt escalation in emergencies [17–19]. Recent Italian deployments, exemplified by the SidlyCare platform, demonstrate the successful clinical integration of wrist-worn devices with certified accuracy and adherence to medical regulatory requirements. The incorporation of artificial intelligence and machine learning into telemedicine platforms has further expanded diagnostic and decision-support capabilities [20,21]. Deep learning architectures, including LSTM-based models, are increasingly applied to detect arrhythmias, hypoxic events and other early-warning signals in real time, thereby improving both clinical outcomes and operational efficiency. Progress in this domain has been reinforced by coordinated efforts among local health authorities, non-profit organizations, patient advocacy groups and general practitioners [2]. Such multi-stakeholder collaboration has been essential for ensuring that digital health technologies remain accessible, contextually appropriate, and sustainable within community-based care models. Collectively, Italy's experience offers a compelling blueprint for remote patient management and underscores a broader transition toward more resilient, inclusive and technologically advanced healthcare systems across Europe.

3. The Proposed Architecture

Figure 1 depicts the architecture of the proposed telemedicine ecosystem, which integrates wearable sensors and artificial intelligence within a resilient, distributed infrastructure to enable

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continuous patient monitoring and timely clinical decision-making. At the patient interface, each participant wears an advanced wristband that tracks key physiological parameters, such as heart rate and peripheral oxygen saturation, using low-power sensors and secure communication modules. Equipped with GPS and Wi-Fi connectivity, these devices transmit encrypted data streams to a central server without interrupting routine daily activities.

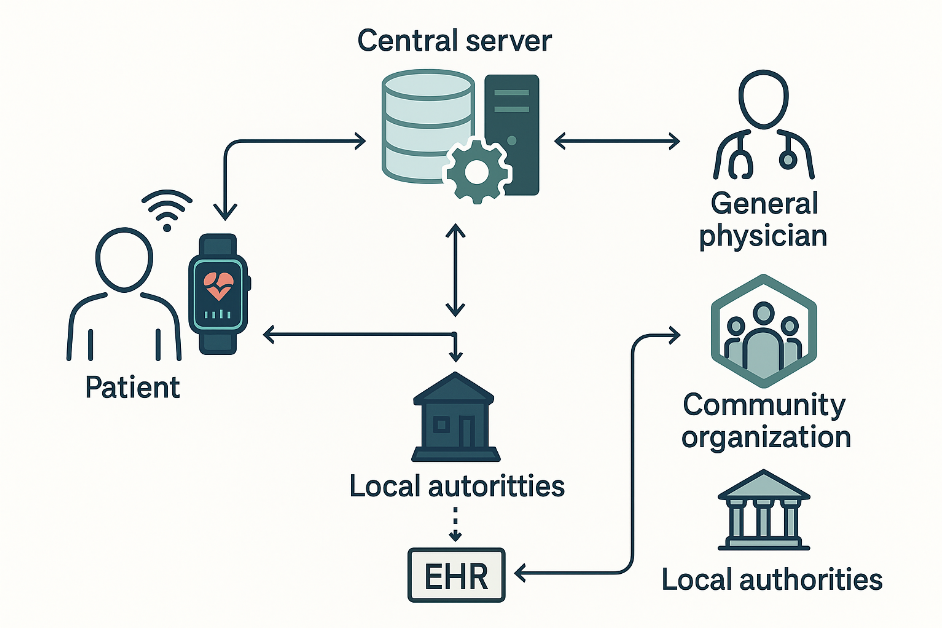

Figure 1. Schematic representation of the telemedicine architecture integrating wearable devices, centralized server analytics, stakeholder dashboards, and data security layers.

The central server serves as the analytical core of the system, responsible for ingesting, storing, and interpreting the high-frequency data generated by the wearables. Leveraging machine learning and real-time analytics, it identifies aberrant patterns or early warning signals that may presage acute medical events. When anomalies arise, the system issues immediate, multi-channel alerts to patients, their general physicians, and, where appropriate, family members or caregivers, thereby enabling rapid, coordinated responses.

The deployment and societal reach of this architecture are reinforced through structured collaboration across multiple stakeholders. Local authorities provide regulatory oversight and logistical support, ensuring that system implementation aligns with regional health priorities. Non-profit organizations, embedded within community networks, extend the platform's capabilities into home-based care settings and sustain patient engagement in tele-home care programmes. General physicians, positioned at the clinical frontline, access secure dashboards that furnish continuously updated patient trajectories, facilitating proactive assessment and timely intervention.

Underlying these services is a comprehensive back-end environment that offers authorized healthcare professionals intuitive dashboards, real-time alerting systems, and longitudinal data visualization tools. These interfaces support scalable monitoring of large patient cohorts and allow customization of alert thresholds, while interoperability modules foster integration with external clinical workflows.

A key attribute of the architecture is its capacity to interface seamlessly with state-level Electronic Health Record (EHR) systems. This linkage ensures that the fine-grained physiological data captured by the wearables can be incorporated into broader clinical care pathways. However, such integration also increases the importance of adherence to interoperability standards, data-protection regulations, and robust consent-management frameworks that safeguard patient autonomy.

Given the sensitivity of health data and the dependence on ubiquitous digital connectivity, the platform adopts a security-by-design paradigm. End-to-end encryption, routine penetration testing, and strict regulatory compliance frameworks collectively protect data integrity and confidentiality.

In summary, the proposed telemedicine architecture represents a unified, technologically advanced model of care shaped by cooperation between local authorities, community organizations, and clinical practitioners. By combing wearable analytics with artificial intelligence and interoperable backend systems, it aims to enhance the early detection of health risks, strengthen continuity of care, and improve healthcare responsiveness, particularly in resource-limited or geographically dispersed regions. Realizing this vision will nevertheless require sustained investment in robust design principles, secure data governance, and coordinated stakeholder engagement to ensure scalable and patient-centred innovation.

4. A Case Study

In the pilot deployment of tele-home care for elderly patients in Calabria, SidlyCare wristbands were used as the primary device for continuous health monitoring. The SidlyCare wristband is a Class IIa certified medical device designed specifically for telemedicine and emergency support, featuring precise pulse and oxygen saturation measurement, fall detection, GPS location tracking, two-way voice communication, and an SOS button for rapid assistance requests. Its power-efficient hardware and ergonomic design make it comfortable for long-term use, even for vulnerable populations such as seniors and those with chronic conditions. All vital sign data generated by the wristbands, including heart rate and SpO_2, are transmitted via secure Wi-Fi or mobile connectivity to a dedicated central server. This server exposes ad hoc APIs for data acquisition and supports integration with external medical platforms as needed. Upon receipt, the measurements are timestamped and stored in a secure patient database.

A bespoke business logic module runs at the server level, applying machine learning-based anomaly detection to time series data. The module includes both classic unsupervised anomaly detection algorithms and deep learning models (e.g., LSTM networks) trained to recognize multivariate anomalies in both heart rate and oxygen saturation trends. These models are optimized to detect both acute events (sudden changes or dangerous thresholds) and subtle, chronic deteriorations. Real-time analyses permit the identification of patterns indicative of cardiac events, respiratory distress, or falls. When an anomaly is detected by the system, immediate alerts are issued. Notifications are sent not only to the patient via the wristband's vibrating alert or audible alarm but are also pushed to caregivers, including family members, assigned care assistants, and, if necessary, the medical call center. General physicians are notified via the backend dashboard and can receive additional mobile or email notifications as needed. Non-profit organizations involved in tele-home care are included in the notification workflow, enabling rapid coordinated response and triage.

Authorized personnel and clinical staff access a secure web-based interface, which aggregates all incoming patient data. The dashboard provides comprehensive visualization of health metrics across timelines, highlights flagged anomalies, and allows for deep data analysis, including historical trends and episode reviews. The platform supports custom reporting, integration with external EHR systems, and the configuration of rules for alerts and follow-ups. Advanced filtering and analysis tools allow physicians and care managers to monitor patient populations, quickly identify emerging risks, and prioritize interventions.

5. Conclusions

In this work, we presented a telemedicine ecosystem tailored to the geographical and organizational specificities of the Calabrian region, integrating certified wearable wristbands, secure communication infrastructure, and intelligent back-end services to support continuous home-based monitoring of fragile patients. By combining real-time physiological data acquisition with advanced anomaly detection algorithms, including deep learning models for multivariate time series, the proposed architecture enables early identification of critical events and timely, coordinated intervention by physicians, caregivers, and community organizations. The SidlyCare-based case study illustrates the feasibility of deploying such a system in mountainous and rural settings, demonstrating how ergonomic, low-power devices coupled with robust dashboards and alerting mechanisms can enhance safety, promote patient engagement, and strengthen continuity of care for elderly populations. At the same time, the tight integration with existing electronic health record infrastructures and adherence to security-by-design principles highlight the centrality of interoperability, data protection, and transparent consent management for scaling telemedicine services in line with national and European regulatory frameworks. Future work will focus on prospective clinical validation, refinement of adaptive and personalized alert strategies, and the extension of the platform to additional patient cohorts and chronic conditions, with the overarching goal of consolidating a resilient, inclusive, and territorially grounded model of digital healthcare for Calabria and similarly underserved regions.

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