ISSN: 2581-3404 (Online) IF: 5.445 (SJIF)
IJIRTM, Volume-7, Issue-5, September-2023.

A Detailed Survey on Remote Home Patient Health Monitoring System (RHMS)

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Abstract: *The Internet of Things (IoT) represents a transformative advancement in internet technology, and its influence is particularly notable in the realm of healthcare research. The utilization of wearable sensors and Smartphones has notably expedited the progress of remote healthcare monitoring. This innovative IoT-enabled health monitoring not only aids in curtailing the spread of diseases but also facilitates accurate health diagnoses, bridging geographical gaps between patients and doctors. This article delves into the escalating demand for healthcare solutions, especially within the elderly demographic. These solutions stem from the aspiration to empower patients and seniors to sustain an autonomous lifestyle within their residences, alleviating the need for excessive dependence on family or caregivers. The primary focal point of this investigation is to conduct an exhaustive appraisal of contemporary remote health monitoring systems. Furthermore, we have identified noteworthy pre-existing RHMS systems, accentuating their potential in revolutionizing healthcare. Lastly, we have meticulously examined and discussed prevailing challenges associated with the evolution of RHMS.*

Keywords: - Internet of Things, Smart health, Sensor, Remote patient monitoring.

Introduction

A remote health monitoring system (RHMS) is an augmentation to a medical facility's existing infrastructure that enables medical practitioners to oversee a patient's vital signs remotely [1]. Previously, detection systems were primarily confined to hospitals and were characterized by large, intricate circuits that consumed substantial power. In the realm of advanced technology, a greater number of sensors and microcontrollers have become prevalent [2]. These modern components are cost-effective, operate at high speeds, and have low power consumption. This technological advancement has paved the way for remote monitoring of crucial life indicators, especially among the elderly and individuals in quarantine due to illness [3]. The integration of a remote health monitoring system with a medical facility's setup facilitates distant observation of a patient's vital physiological parameters.

- A remote health monitoring system finds application in various scenarios:
- Situations involving critical organ functions
- Individuals in quarantine due to the impact of the coronavirus
- Instances where a patient is diagnosed with a medical condition affecting a volatile regulatory system, especially when a new medication is administered
- Cases involving critical organ conditions

- Situations where potentially life-threatening illnesses emerge, particularly concerning the elderly or those with compromised health
- Individuals quarantined due to contracting the coronavirus

To address the challenges posed by remote health monitoring, several innovative technologies have emerged. Diverse solutions have been recently developed to tackle the complexities of remote health monitoring [4].
Presently, the Internet of Things (IoT) has found widespread adoption across various applications, extending its significance to daily life [5]. IoT technology is also making strides in healthcare monitoring systems, contributing to efficient emergency medical services for patients (Figure 1). Additionally, it's being employed in E-health applications, encompassing early detection of medical issues, emergency notifications, and computer-assisted rehabilitation [6]. Smartphones have seamlessly integrated into people's daily routines and are linked to sensors for subject health monitoring. This sensor-based surveillance system collects data from wards and diagnostic equipment, utilizing the information for streamlined and automated healthcare management [7].

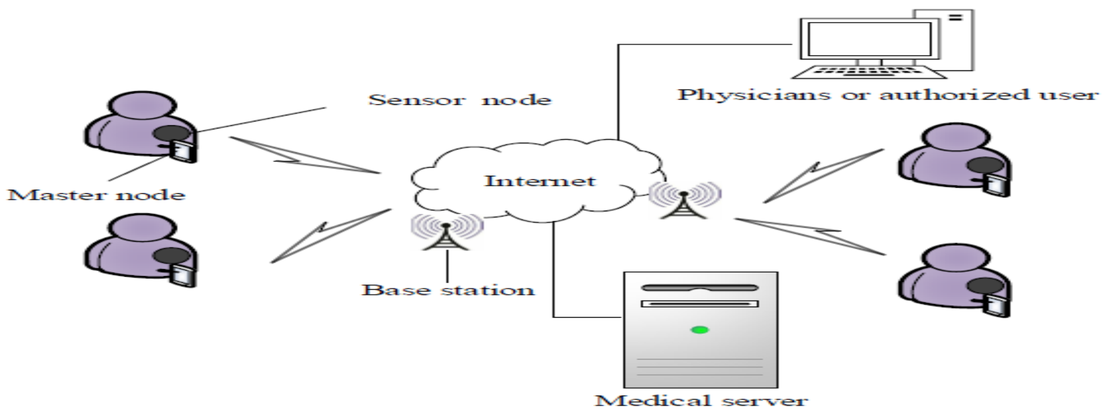

Figure 1: IoT healthcare system.

The Internet of Things (IoT) healthcare framework introduces effective monitoring and tracking mechanisms that enhance people's resource management [8]. Cloud computing is harnessed to manage healthcare data, offering resource-sharing features such as flexibility, integrated data services, scalable data storage, parallel processing, and early identification of security issues [9]. However, in IoT-based healthcare systems, the wearable devices or sensors embedded in patients have limited battery capacity. Frequent recharging of these devices and mobile gadgets can lead to patient fatigue and necessitate nurse intervention, negatively impacting the user experience [10]. Furthermore, energy consumption within cloud data centers is notably high, subsequently inflating cloud computing costs. It is essential for a health monitoring system to have low latency and energy-efficient cloud services [11]. Addressing another concern, data security in healthcare monitoring is susceptible to manipulation by attackers or hackers. Consequently, it is imperative to develop a privacy-preserving IoT-based healthcare system that seamlessly integrates with patients to ensure efficient data transmission.

II. Basic Elements of RHMS

The fundamental components of a remote monitoring system encompass:

- Data Acquisition System- Comprising diverse sensors or sensor-equipped devices capable of wireless data transmission. As technology progresses, sensors are not limited to medical sensors alone; they can include cameras or Smartphones.

- Data Processing System- Handling the vast volume of information generated by IoT services, contributing to the phenomenon of big data. Advances in parallel computation architectures, like Graphics Processing Units (GPUs), offer the potential to accelerate complex data computations.
- End Terminal at the Hospital- This terminal can be a hospital computer, a dedicated device, or a doctor's smartphone. The communication network connects the data acquisition system to the data processing system, facilitating the transmission of data and conclusions to healthcare professionals via the communication network.
- Communication Network- A vital aspect of many smart healthcare applications, require low-latency, high-throughput, and low-power communication. The evolution of the Health Internet of Things (HIoT) hinges on hierarchical network structuring (e.g., utilizing cloudlets) and the maturity of Wireless Body Area Networks (WBANs).

III. Sensors used for RHMS

The system entails hardware components crucial for prototype development [10]. These components include a microcontroller with a built-in ADC, a blood pressure sensor, a contactless temperature sensor, and an oximeter (as depicted in Figure 2). The COVID-19 virus typically enters through the nostrils and mouth, making its way to the human respiratory system [12].
Elevated blood pressure has been observed in COVID-19 cases, thus rendering blood pressure measurement a crucial parameter in COVID detection. Monitoring the temperature and oxygen levels of COVID patients plays a pivotal role in identifying potential COVID-19 cases [13]. Notably, COVID-infected individuals often experience a significant reduction in oxygen levels, prompting the utilization of oximeters to gauge oxygen saturation. To facilitate data collection, all sensors are integrated with a microcontroller, specifically the Raspberry Pi. This setup enables data recording and transmission to the cloud for storage and subsequent analysis [14]. The sensor array employed within the Remote Health Monitoring System (RHMS) is illustrated in Figure 3.

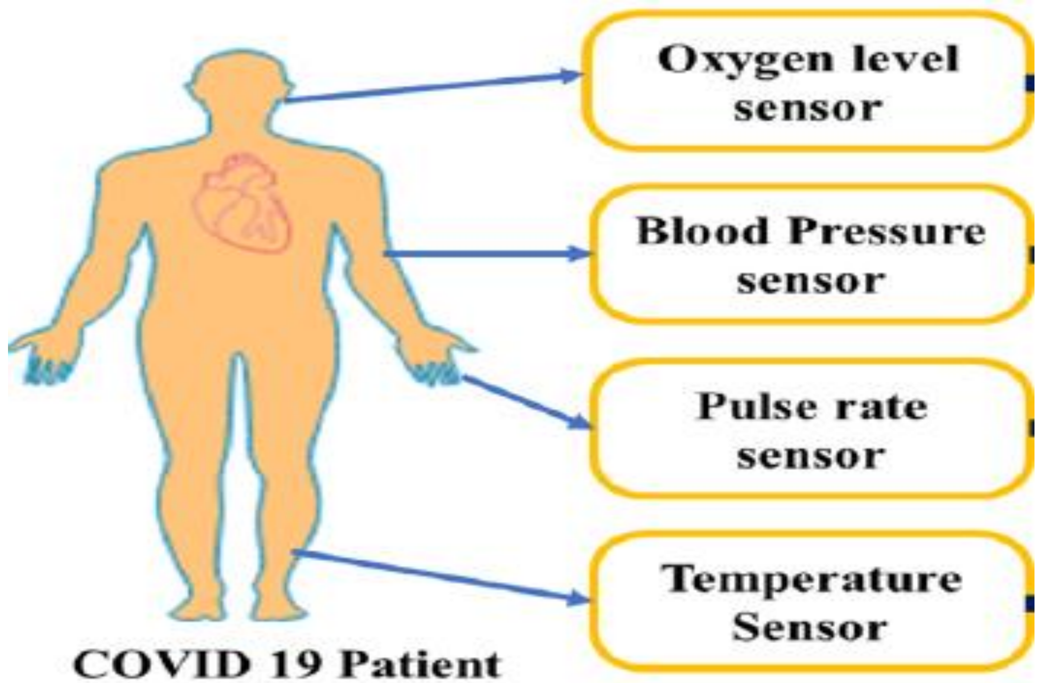

Figure 2: A Patient in RHMS.

(a) Blood-pressure (b) temperature sensor (c) Pulse Oximeter

Figure 3: Sensors used in RHMS.

➢ Blood Pressure Sensor- The blood pressure sensor is affixed to the arm, providing three distinct data readings to the microcontroller. These readings encompass systolic, diastolic, and pulse rate measurements, all of which are transmitted to the Raspberry Pi.

➢ Temperature Sensor- Placed in proximity to the human body, the temperature sensor captures temperature values without requiring physical contact with patients. This sensor is equipped with a low noise amplifier, a 17-bit ADC, and a robust DSP unit, thereby achieving exceptional accuracy and resolution in temperature measurement.

➢ Pulse Oximeter- Utilizing the MAX30100 module, the pulse oximeter integrates pulse oximetry and heart rate monitoring capabilities. This module incorporates two LEDs, a photo detector, optimized optics, and low-noise analog signal processing to detect both pulse rate and heart rate signals.

IV. Applications of RHMS

➢ Activity Recognition- Activity recognition finds utility in diverse healthcare domains, employing techniques such as computer vision [15], active sensor beacons, passive radio-frequency identification (RFID), WiFi, and radar. Nevertheless, many conventional activity recognition systems suffer from elevated false-positive rates when identifying abnormal activity.

➢ Stroke Rehabilitation- Rehabilitation for stroke patients is a significant undertaking explored from various angles. The trend leans toward self-managed rehabilitation, using virtual environments for patient recovery, forecasting muscle strength based on kinematics, and tracking activities to assess recovery progress, illustrating the potential of Health Internet of Things (HIoT) in stroke rehabilitation [16].

➢ Blood Glucose Monitoring- Diabetes affects around 9.4% of the US population (approximately 30.3 million individuals) making blood glucose monitoring crucial. This practice offers vital insights for managing diabetes and maintaining health.

➢ Cardiac Monitoring- Cardiovascular disease accounts for a third of US deaths, holding the top spot as the leading cause of mortality. Personalized and continuous cardiac monitoring, distinct from conventional in-hospital monitoring, contributes significantly to curbing cardiovascular disease fatalities and reducing associated expenses.

➢ Respiration Monitoring- Monitoring patients' respiration offers valuable insights into their overall well-being. Devices for respiration monitoring can be categorized as contact-based or non-contact. Their applications range from monitoring newborns for sudden infant death syndrome to assessing the impact of medications on respiration and monitoring asthma patients [17].

➢ Sleep Monitoring- IoT devices are employed to monitor patients during sleep, serving purposes like sleep stage classification, monitoring vital signs, and detecting sleep disorders such as obstructive sleep apnea.

➢ Blood Pressure Monitoring- With a prevalence of approximately 45.6% among US adults, high blood pressure is a critical health concern. IoT-based hypertension monitoring systems are already in use, with some applications capable of participating in hypertension management decisions.

- Stress Monitoring- Various systems exist to monitor different stress levels and intervene when necessary. While mild stress is common, excessive stress can lead to severe health complications.
- Medical Adherence- Ensuring patients adhere to their healthcare regimens poses a significant challenge. IoT devices offer solutions for monitoring adherence, particularly for the elderly, individuals with dementia, and general medical adherence monitoring, thereby ensuring proper regimen adherence.

V. Related Review

To improve the performance of remote health monitoring systems, many studies have been carried out. This section of the paper has reviewed contributions of existing works and then implemented the proposed design.

Nafisa Shamim Rafa et al. [1] in their research have demonstrated the creation of a distant health and environmental assessment system, particularly for asthma patients at high risk during COVID-19. Since prompt treatment is crucial, their remote IoT system enables physicians and other medical professionals to get patient data in real-time and provide services to patients without consideration of their location.

Auday A.H. et al. [2] have primarily focused on the use of IoT technology in the field of health applications. The goal is to give patients access to a trustworthy healthcare analytics platform that can be used by medical professionals to monitor patients, as well as an ECG diagnostic system using the ThingSpeak IoT platform capability analysis.

Veneeta et al. [3] have suggested employing technology to improve patient lives for quicker treatment and diagnosis. IoT is used to create an intelligent health tracking system that can track a person's temperature, heart rate, blood pressure, and oxygen saturation.

V. Kamalkumar et al. [4] intend to make it possible for experts to remotely monitor patients in order to reduce the load and deal with the dangerous situation generated by the pandemic. They employ a range of sensors, including the BT sensor (LM35), Glucose measurement, and Pulse sensor (SEN11574) system, to continuously track the patient's everyday health, including measuring the patient's pulse, temperature, heartbeat, and other metrics.

The main goal of Sangeetha Lakshmi et al. [5] was to develop a reliable patient management system based on IoT so that healthcare professionals can monitor their patients who are either hospitalized or at home employing an IoT depending combined RHM medical system in order to guarantee high-quality patient care. Wi-Fi network-based sensing and data collection were employed.

On a different note, Adam et al. [6] have presented a study and concluded that BT and the mass of humans are inversely correlated. To design wearable apparatus, Aditya Chowdhary et al. [7] have suggested a medical device for RHM that is IoT-based. It aids the doctors, nurses, and patient's friends in keeping updated on several important health data, including heartbeat, BT, and blood oxygen levels, using the BlynkApp on the ThingSpeak cloud.

An IoT-based RHM system was created by M. I. Abdullah et al. [8] that enables medical personnel to remotely monitor BT, HR, and blood saturation..

Hemanth Kumar et al. [9] proposed using IoT to continually monitor the patient's blood pressure, room temperature, and heart rate. Furthermore, the temperature can be adjusted as needed..

Ruhul Amin et al. [10] developed biomedical sensors connected with a microcontroller that collects data on HR, BT, and body movement to provide a description of the patient's current health status.

The design and deployment of a health monitoring IoT-based network that includes temperature as well as pulse rate sensors are presented by A. D. Priya et al. in their publication from 2011 (11).

Multiple kinds of sensors have been compared to examine how they operate differently by S. Nookhao et al. [12]. The constructed system's performance was evaluated by three computer specialists and found to be at a good level.

Wasana Boonsong et al. [13] have proposed a wireless BT invention in place of the manual system utilized by hospital medical professionals for "the Contactless BT monitoring (CBTM) in non-patient department (IPD).

VI. Challenges in RHMS

IoT has found application across various healthcare domains, supporting patient monitoring and enabling smart home systems for individuals with diabetes. However, several major challenges persist within the healthcare system:

- Flexibility vs. Patient Comfort- IoT introduces flexibility, enabling patients to receive continuous care at home rather than in a hospital. Nonetheless, the use of wearable sensors might lead to discomfort for patients due to their presence on the body.
- Data Quality and Transmission- Data from sensors to control devices and subsequently to monitoring centers can be impacted by noise, affecting data quality. Improved architectural design and noise removal techniques are essential to maintain data integrity.
- ECG Monitoring Methods- Current ECG monitoring methods often entail supervised signal analysis, which can be costly and error-prone. Implementing machine learning for signal analysis can enhance efficiency and reduce expenses.
- Energy Consumption- The growing number of sensors and devices in IoT systems requires increased energy for processing, leading to higher power leakage and energy consumption. Optimization algorithms can mitigate energy consumption.
- Storage and Complexity- Monitoring numerous users in IoT demands substantial storage and computational resources. Cloud storage offers a solution, yet integrating IoT with the cloud can introduce complexity.
- Privacy and Security- IoT devices are vulnerable to attacks, posing privacy concerns. Their resource-constrained nature makes encryption techniques challenging to apply.

While several research efforts have been dedicated to designing and implementing IoT healthcare systems, numerous challenges and open issues remain. The subsequent section elaborates on the various challenges within IoT healthcare services.

- Scalability- Scalability is pivotal in healthcare systems, encompassing a device's adaptability to environmental changes and future needs. However, IoT healthcare systems often lack scalability due to the multitude of connected sensors, actuators, and devices with differing characteristics. Managing these devices necessitates appropriate addressing conventions, protocols, and power to ensure scalability and uniformity.
- IoT Healthcare Security- The preservation of data privacy and security constitutes a significant challenge in IoT-based healthcare applications. Security involves credential management and access control for applications and confidential patient information. Data privacy is of paramount importance, given that healthcare apps are built around data from IoT devices. The immense data flow, often hacked, can be misused to compromise patients' and doctors' interests.
- Low Power in IoT Healthcare Device- Typical IoT healthcare networks comprise small devices with limited battery capacity. These devices conserve energy by activating power-saving modes when not transmitting sensor readings. However, due to various service requirements, these devices may experience power shortages, even when in power-saving mode.
- Network Architecture- IoT network architectures for healthcare must ensure user authentication and authorization. While various network architectures have been proposed, the traditional three-layer architecture falls short in meeting healthcare application demands. The more recent five-layer IoT architecture has limitations in terms of storage and energy capabilities.

➢ Cost Analysis of IoT Healthcare System- Presently, healthcare device costs significantly impact IoT systems. Despite the advancements, there's a dearth of comparative cost analysis for IoT healthcare systems. The high expenses associated with monitoring equipment pose a substantial challenge, even in developed nations.

➢ App Development Process- Mobile app developers grapple with security, privacy, and database technology challenges. Numerous devices can be managed, monitored, or maintained through apps, raising concerns about safeguarding patient/user data from breaches and ensuring data sharing with patient consent.

➢ Quality of Services (QoS)- The real-time nature of IoT usage for decision support underscores the importance of Quality of Service (QoS). Healthcare sensor-generated data needs timely collection, transmission, processing, analysis, and application. However, there are instances where IoT devices fail to deliver data promptly, posing QoS challenges for healthcare systems.

➢ Continuous Monitoring for Healthcare Purpose- Long-term monitoring, especially for the elderly and chronic patients, is critical. Consistent monitoring and data logging are essential. To achieve this, smart devices and sensors must transmit data reliably to the designated destinations on time.

VII. Key Technologies For IoT Based RHMS

The structure of IoT-based in-home health monitoring systems generally comprises five pivotal IoT technologies, depicted in Figure 4.

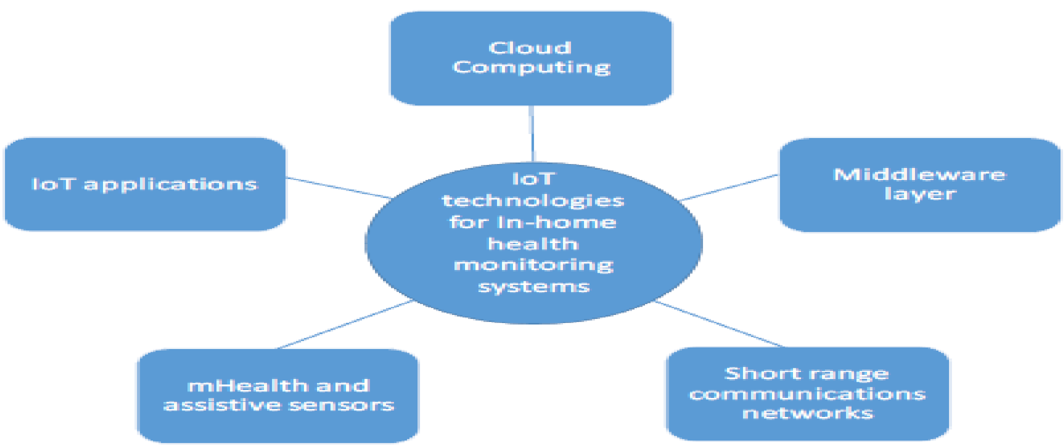

Figure 4: Key technologies for IoT based RHMS.

Derived from these five technologies, the ensuing subsections outline the latest progressions in IoT technologies and services tailored for applications in in-home health monitoring.

➢ mHealth and Assistive Sensors- This category encompasses both invasive and non-invasive sensors employed to monitor biomedical signals and changes in the living environment. Biomedical signals are contingent on an individual's lifestyle and medical conditions (such as diabetes, COPD, cancer, and mental disorders). Conditions like these necessitate parameter management and control, such as glucose levels, blood pressure, temperature, ECG, and weight. This requirement drives the utilization of sensor devices to measure these conditions.

➢ Short-Range Communications Networks- This section discusses Wireless Sensor Networks (WSN) and Personal Area Networks (PAN) as short-range communications networks. WSNs consist of sensor arrays that monitor diverse health conditions or assistive living aspects. When individuals need to wear these sensors, it is referred to as a Wireless Body Area Network (WBAN). PANs facilitate communication between sensors and personal computer devices.

- Middleware Layer- Positioned as a service-oriented software layer, the middleware layer bridges communications between heterogeneous devices such as sensors and actuators on one end and cloud services on the other. It abstracts the underlying sensor functionality, acting as an intermediary between the cloud and sensor devices. Its role involves collecting sensed data and transmitting it to the cloud platform.
- Cloud Computing- Cloud computing constitutes another subsystem within in-home health remote monitoring systems. This internet-based computing platform provides data storage for collected data from various IoT devices and sensors, servers for processing and analyzing the gathered data, and intelligent systems that leverage analyzed data to generate alarms and insights supporting decisions made by healthcare professionals for patient treatment

VIII. Security And Privacy Challenges In Healthcare

Medical records are undergoing a shift towards digital formats, stored in Electronic Health Records (EHRs) that can be accessed online via cloud servers. However, cloud server security can be breached by attackers, leading to unauthorized access to patients' medical data. This section elucidates the security and privacy challenges present in Healthcare 4.0:

- Ethical Challenges- Issues like data confidentiality, data privacy, data access control, profit orientation of patient information, and data possession hinder smooth data exchange between patients and Healthcare Service Providers (HSPs).
- User Authentication- Access to patient records in EHRs is limited to authorized users. However, attackers can compromise user identities to gain access to patient information.
- Confidentiality and Integrity- Confidentiality protects sensitive information from unauthorized users, while integrity ensures data accuracy. Adversaries can modify stored information, leading to data inaccuracies.
- Data Ownership- Data ownership pertains to who possesses and accesses the data. Attackers can manipulate ownership details to establish false ownership, underscoring the importance of safeguarding ownership data from unauthorized access.
- Data Protection Policies- Ensuring the security and stringent management of health diagnostic data is vital to prevent loss or theft. Developing a secure EHR system with multiple security levels is a complex challenge [9].
- Misuse of Health Records- Some online EHR systems provide limited free storage space without adequate data privacy measures. These platforms might exploit patient information by selling it to other companies or advertising agencies.

IX. Conclusions

The healthcare sector is undergoing rapid technological and service-oriented advancements. An emerging trend in this field involves the remote monitoring of patients, a particularly beneficial innovation given the global population's swift aging and the subsequent surge in health complexities. What began as basic applications for in-hospital patient monitoring has evolved significantly, enabling patients to resume their daily routines at home while still being under surveillance, facilitated by modern communication and sensor technologies. This scope of remote healthcare spans from overseeing patients with chronic conditions, senior citizens, and preterm infants to individuals affected by accidents. These novel technologies offer monitoring solutions tailored to specific ailments or circumstances. This study provides an overview of existing literature on remote patient monitoring systems, covering areas such as cardiovascular and hematology-related systems, fall detection mechanisms, neurological systems pertaining to the brain and nervous system, diabetes management, and mental health research.

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