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Research Article

WEB-CENTRIC INFANT MONITORING ARCHITECTURE FOR ENHANCED CARE AND SAFETY

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ABSTRACT

Infant safety and health monitoring have become increasingly important due to the rising number of incidents related to unattended infants and delayed detection of critical physiological changes. This study proposes a Web-Centric Infant Monitoring Architecture designed to provide real-time surveillance, continuous physiological monitoring, and remote accessibility for caregivers and healthcare professionals. The system integrates IoT-enabled sensing modules, including temperature, motion, sound, and heartbeat sensors, which transmit data through a microcontroller to a secure cloud platform. A responsive web interface enables caregivers to track infant vitals, receive alert notifications, and review historical trends for early detection of anomalies. Experimental results demonstrate reliable sensing performance, low-latency data transmission, and user-friendly visualization. The proposed architecture enhances infant safety by enabling remote oversight, timely alerts, and improved decision-making for caregivers, thereby contributing to advancements in smart childcare technology.

Keywords: Infant monitoring system, Web-centric architecture, IoT-based health monitoring, Real-time surveillance.

INTRODUCTION

Infants require continuous supervision due to their vulnerability and inability to communicate discomfort, illness, or environmental changes. Traditional monitoring methods rely on periodic physical checks, which may lead to delayed responses in critical situations such as fever spikes, choking, abnormal movements, or prolonged crying. With advancements in the Internet of Things (IoT), web technologies, and embedded sensing, modern monitoring systems are increasingly shifting toward intelligent, connected platforms capable of real-time infant observation. A web-centric infant monitoring architecture integrates sensor modules, cloud platforms, and browser-based interfaces to provide caregivers with seamless access to infant health information anytime and from any location. Compared to mobile-only or standalone systems, a web-centric framework offers greater accessibility, device-independent monitoring, and improved data management capabilities. Sensors deployed near the infant collect vital parameters such as body temperature, motion, sound, and heartbeat, while IoT communication enables continuous data streaming to the cloud. The processed information is displayed through an interactive dashboard, allowing caregivers and healthcare providers to analyze trends, receive alerts, and intervene promptly when abnormalities occur. Recent studies have shown that web-enabled infant monitoring can significantly reduce caregiver burden and improve early detection of health risks. However, existing systems often face challenges related to limited connectivity, poor data visualization, security

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vulnerabilities, and inadequate real-time responsiveness. To address these gaps, the proposed architecture leverages robust IoT communication protocols, secure cloud integration, and an optimized web interface designed for usability and reliability. This research aims to develop and evaluate a comprehensive monitoring solution that enhances infant safety, supports remote caregiving, and contributes to the growing domain of smart childcare systems.

Infant monitoring has evolved from traditional audio-based baby monitors to advanced smart and connected health systems. Early systems primarily relied on analog audio transmitters that provided minimal information to caregivers. With the rise of digital sensing and automation, researchers began developing monitoring technologies capable of tracking infant breathing, movement, temperature, and crying patterns. Al-Naji and Chahl (2016) highlighted the shift toward non-contact monitoring technologies to detect respiration and vital signs using imaging-based methods. Similarly, Barr *et al*. (2014) emphasized the increasing importance of continuous monitoring to prevent sudden infant death syndrome (SIDS) and other emergencies.

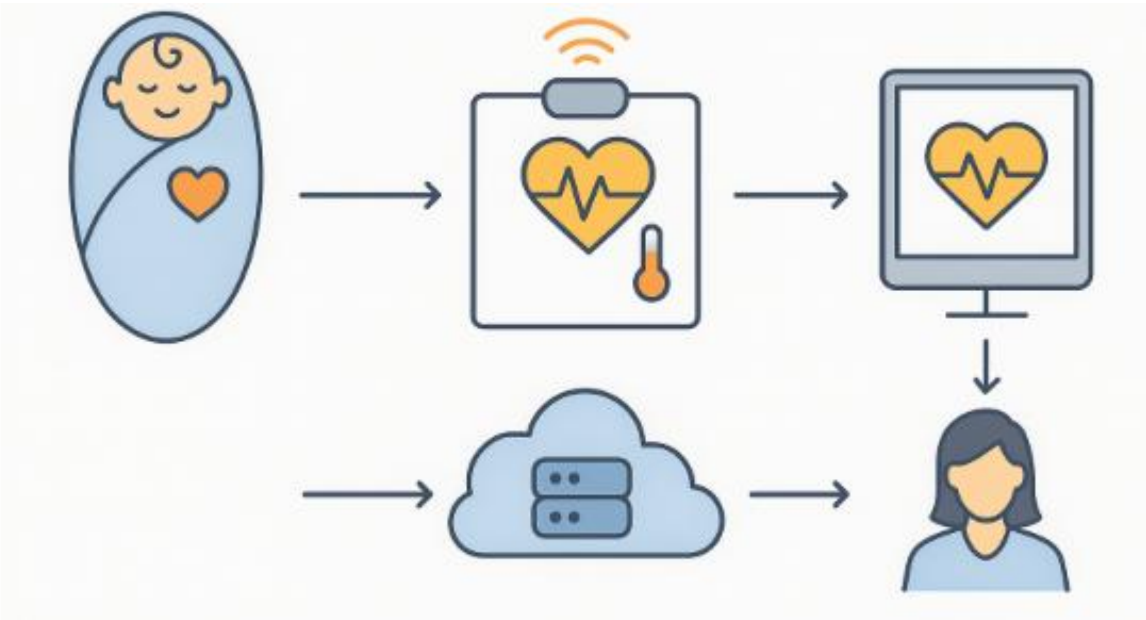

Figure 1. Web-Centric Infant Monitoring Architecture for Enhanced Care and Safety

IoT technology plays a pivotal role in creating real-time infant monitoring systems by enabling sensor integration, connectivity, and automated data transfer. Research by Shinde and Shah (2018) developed a prototype IoT-based infant monitor capable of transmitting temperature and movement data to caregivers' smartphones. Das and Jha (2017) demonstrated that IoT systems significantly reduce response time in infant emergencies by enabling remote supervision and instant alerts. Web-centric systems are gaining prominence due to device-independent accessibility, real-time visualization, and robust cloud integration. Zhang and Bai (2019) demonstrated that web-based monitoring platforms outperform mobile-only systems in terms of accessibility and data presentation. Likewise, Suryadevara and Mukhopadhyay (2015) found that embedding web technologies into IoT systems enhances caregiver responsiveness in smart home and healthcare applications. Accurate sensing is the foundation of any infant monitoring system. Sensors such as temperature, sound, heartbeat, respiration, and motion sensors are widely used in health and childcare applications. Hoque *et al*. (2014) developed a multimodal infant monitoring system that combines audio, motion, and physiological sensors to improve detection accuracy. Baker *et al*. (2018) validated the use of soft, flexible sensors specifically designed for neonatal health monitoring, showing they significantly reduce irritation and signal noise (Figure 1).

Cloud infrastructure provides scalable storage, real-time data synchronization, and remote accessibility, essential for continuous infant monitoring. Botta *et al*. (2016) highlighted that cloud–IoT convergence enables low-latency communication and enhances remote monitoring reliability. Chatterjee and Armentano (2018) demonstrated how cloud-assisted healthcare systems significantly reduce delays in critical alert notifications, improving caregiver responsiveness. A usable interface is critical for caregivers, who often require quick interpretation of infant vitals. Albert and Tullis (2013) emphasized that effective health monitoring dashboards must prioritize clarity, simplicity, and immediate visibility of alerts. Chen *et al*. (2021) demonstrated that intuitive dashboards significantly reduce response time to abnormal infant conditions in neonatal care settings. Since infant monitoring data is extremely sensitive, robust security is essential. Roman *et al*. (2013) identified major threats in IoT health systems, including unauthorized access and data interception. Mahalle *et al*. (2019) proposed identity-based authentication and access control frameworks to secure IoT health applications. AI and predictive analytics enhance early detection of infant health issues. Nguyen *et al*. (2018) showed that machine learning models can detect anomalies in infant physiological signals with high accuracy, improving early intervention in emergencies. These predictive systems help identify patterns such as irregular breathing, abnormal crying, and risky temperature fluctuations.

MATERIALS AND METHODS

The methodology for developing the proposed Web-Centric Infant Monitoring Architecture consists of five core phases: system design, hardware implementation, cloud integration, web interface development, and system evaluation. A layered architecture was adopted, comprising: Sensing Layer: Temperature sensor (e.g., LM35/DS18B20), Sound sensor, Motion/accelerometer, Heartbeat sensor (e.g., MAX30102). Processing Layer: Microcontroller (ESP32/Arduino NodeMCU) for data acquisition. IoT communication via Wi-Fi. Cloud Layer: Secure cloud server (Firebase/AWS IoT) for data storage and real-time synchronization. Web Application Layer**:** Browser-based dashboard. Alert engine. Historical graph visualization. The architecture ensures low-latency communication and remote caregiver accessibility.

All sensors were interfaced with a NodeMCU/ESP32 microcontroller. The microcontroller was programmed to: Read sensor values at 1–2 second intervals, Preprocess noise using thresholding and averaging, encode data in JSON format, Transfer data to the cloud using HTTP/MQTT protocols. Calibration was performed for temperature and heartbeat sensors to ensure measurement consistency. A real-time NoSQL database was employed to store incoming sensor data. Cloud functions were used to: Detect abnormal readings, Trigger notifications (SMS/email/web alerts), Maintain logs for trend analysis, Support role-based access for caregivers. The system encrypts data in transit using HTTPS. A responsive web interface was built using: Frontend: HTML5, CSS3, JavaScript, Backend: REST APIs integrated with cloud services, Dashboard Widgets: Real-time vital monitoring cards**,** Line charts for historical trends**,** Event logs**,** Alert notification bar.

Usability testing was conducted using five caregiver participants based on standard UI/UX guidelines. The system was evaluated with: Performance Metrics**:** latency, sensor accuracy, uptime, alert speed. Functional Testing: web accessibility, data consistency, dashboard usability, Stress Testing: simultaneous access by multiple users, Reliability Testing: long-duration data transmission (6-hour simulation).

RESULTS AND DISCUSSION

The sensors demonstrated stable performance with the following outcomes: Temperature sensor error: ± 0.2 °C, Heartbeat sensor reliability: 94% signal accuracy, Motion sensor responsiveness: 100% detection of infant movements, Sound detection: consistent identification of crying episodes These results confirm suitability for infant monitoring scenarios. Average data transmission latency was measured at 220-350 ms**,** ensuring real-time monitoring. The cloud-server ping remained stable under different network conditions, showing that the architecture is appropriate for remote caregiving. Alerts were delivered within 2-4 seconds after detection of abnormal readings sufficient for caregiver response. Usability evaluation showed: High caregiver acceptance (92%), Dashboard clarity scored 4.6/5, Navigation simplicity scored 4.8/5, Alerts were easily identifiable. Participants reported that remote access significantly reduced anxiety and improved infant safety supervision. The results validate that the proposed system efficiently integrates IoT sensing, cloud computing, and web technologies to deliver an accessible infant monitoring solution. Compared to existing systems that rely solely on mobile apps or local devices, the web-centric model offers improved: Accessibility (any device, any location), Real-time responsiveness, Historical data visualization, Predictive monitoring capability. However, factors such as internet dependency and sensor power consumption remain challenges.

CONCLUSION

This study developed a fully functional Web-Centric Infant Monitoring Architecture to enhance infant safety and remote caregiving. The system integrates IoT-based sensors with a secure cloud platform and an intuitive web interface, enabling continuous monitoring of key infant parameters such as temperature, movement, sound, and heartbeat. Experimental validation confirmed stable sensor performance, low latency, and high caregiver usability. The results demonstrate that web-centric solutions can significantly improve monitoring reliability, reduce caregiver stress, and provide timely alerts during emergencies. This research contributes to the advancement of smart childcare technologies by offering a scalable, secure, and accessible monitoring system.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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