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Repurposing medical hardware in Thailand for a caregiver alert system with no-code application

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ABSTRACT

As Thailand's aging population places an escalating burden on its healthcare system, innovative approaches to community-based care are essential. With the number of bedridden elderly projected to nearly triple by 2030, our work addresses this challenge by repurposing existing medical hardware with accessible IoT technology. We developed a remote monitoring system centered on a mobile application built with a no-code platform, using a cloud-based backend. This enables rapid, low-cost development, placing powerful tool-creation capabilities directly into the hands of healthcare professionals. The application provides caregivers with a real-time dashboard and instant alerts to remotely track patient conditions, featuring distinct access levels to ensure data privacy. To demonstrate the capabilities, we retrofitted a standard nursing bed to monitor patient activity and elevation and digitized a blood pressure monitor for interval-based tracking. Preliminary system validation under a controlled environment confirmed high reliability, achieving 100% classification accuracy for bed occupancy and a maximum error of 2° for head-of-bed elevation. A key finding from our analysis is the significant power consumption overhead associated with IoT enablement, resulting in an increase in idle power from 0.86 W to 1.09 W, with the FMCW sensor being the primary consumer (63.6%). Furthermore, a cost-benefit analysis indicates a 67–85% reduction in implementation costs compared to commercial alternatives ($100–175 vs. >$275). This study contributes a validated engineering framework for the sustainable digitalization of legacy medical assets. By quantifying the trade-offs between power and performance and demonstrating that commodity sensors integrated with no-code platforms can achieve high reliability, the work establishes a scalable, low-barrier model for transforming healthcare infrastructure in resource-constrained environments.

Keywords: IoT-based healthcare, Assistive monitoring, Caregiver alert system, Remote patient monitoring, No-code application

INTRODUCTION

Thailand is heading toward a major demographic transformation, becoming a fully aged society where more than 20% of its population is over 60. This transition, one of the fastest in Southeast Asia, is escalating pressure on its healthcare system, primarily due to the increased prevalence of age-related chronic conditions such as hypertension, diabetes, and heart disease [1, 2]. A critical consequence of this shift is the projected surge in the number of frail individuals requiring long-term care. It is estimated that the number of bedridden elderly patients, defined by a low Activities of Daily Living (ADL) index, will reach approximately 153,000 by 2030, which is a near threefold increase from the previous decade [3]. This escalating need for continuous, long-term management of chronic illness creates a significant challenge for the small-to-medium-sized healthcare facilities, community health centers, and nursing homes that form the backbone of primary elder care, especially in rural areas [4]. In response to this demographic pressure, remote patient monitoring (RPM) has emerged as a powerful tool. For the elderly managing multiple chronic conditions, RPM enables early detection of health decline, supports timely interventions, and ultimately improves patient outcomes, allowing many to *age in place* safely [5]. However, a significant gap exists between the potential of RPM and its practical implementation. While new medical devices often feature integrated IoT capabilities, a vast installed base of functional, non-networked legacy equipment remains in service. For smaller healthcare facilities and nursing homes, which provide the majority

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of elder care, the capital outlay required to replace these systems with smart counterparts is simply prohibitive [6]. This financial barrier is compounded by operational hurdles: a lack of specialized IT staff, the need for digital literacy training for caregivers of the elderly, and fragmented data systems that prevent integrated coordination of complex care plans. Consequently, a critical service gap has formed. The very elderly population that stands to benefit most from continuous, data-driven monitoring for their chronic conditions is often served by the facilities least equipped to provide it. This creates an urgent need for pragmatic solutions that can bridge this technological divide without demanding a complete and financially unfeasible infrastructural overhaul.

Recent research addresses the challenge of providing affordable elderly care through several key approaches. A primary strategy involves retrofitting legacy medical equipment, such as standard nursing care beds, with low-cost smart sensors to monitor patient vitals and movement without requiring expensive replacement [7]. This captured data is then typically channeled via integrated IoT platforms for real-time analysis and alert generation; a solution aimed at overcoming the infrastructure and financial hurdles common in smaller facilities. Within the specific context of Thailand, there is a strong emphasis on creating accessible, mobile-first solutions that leverage its high smartphone penetration among the elderly [8]. This trend is validated by public and private initiatives leveraging no-code/low-code development platforms. These platforms are crucial as they empower non-technical staff, such as nurses, to become citizen developers who can build and modify applications themselves [9, 10]. This approach reduces development costs and time-to-market, enabling affordable, practical solutions to be deployed rapidly to meet the specific needs of a community healthcare environment.

This paper presents a case study of a cost-effective IoT remote monitoring system designed to be accessible to caregivers in resource-constrained settings. It addresses these disparities by proposing a privacy-preserving, non-contact, and no-code solution that eliminates the need for specialized IT maintenance. Another core advantage is its economic sustainability; rather than requiring investment in new equipment, it modifies existing assets by retrofitting and repurposing them with simple sensors. This approach is achieved through a mobile application built on Google Sheets and AppSheet [11], a no-code platform that eliminates the need for specialized developers and dramatically reduces implementation costs. This system is immediately practical for smaller facilities, offering real-time data visualization and alerts through a user-friendly interface. It allows for both comprehensive and individual patient views with distinct access levels for caregivers. The current prototype, which integrates a retrofit nursing bed and a continuous vital signs monitor, demonstrates a realistic and scalable model that could be replicated in similar resource-constrained healthcare environments throughout the region.

MATERIALS AND METHODS

This research outlines a methodology for developing and implementing an IoT-based remote monitoring and alert system. The approach focuses on the cost-effective retrofitting of existing medical equipment to enable smart, connected functionalities. The methodology is presented in two main parts: first, the overall system architecture is described, detailing the framework for data acquisition, cloud-based processing, and user interaction through a mobile application. Second, the paper elaborates on the specific engineering processes for retrofitting two key medical devices: a nursing care bed and a blood pressure monitor with custom IoT-enabled modules. Finally, the application interface is discussed.

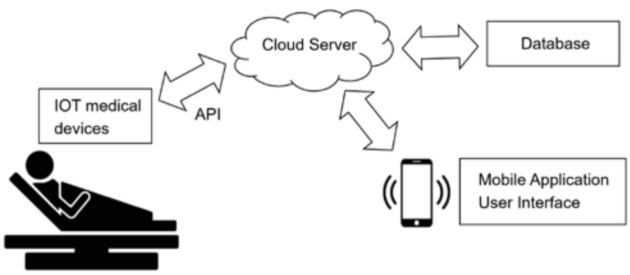

Figure 1 A framework for remote monitoring.

Overview of the remote monitoring framework

The system architecture (Figure 1) utilizes an IoT medical device layer for the real-time acquisition of patient vitals. To accommodate the limited SRAM capacity of these low-cost microcontrollers, the firmware employs the BearSSL WiFi client. This ensures HTTPS (TLS 1.2) communication and stable connections during cold-start conditions without excessive memory consumption. Sensor data are transmitted as lightweight JSON payloads via HTTPS POST requests to a cloud middleware implemented in Google Apps Script. This approach is preferred over directly interfacing with the standard Google Sheets API, which would impose significant computational overhead on the device [12, 13]. By acting as a buffer, the middleware allows the IoT nodes to function as stateless clients while isolating database-specific logic. To support concurrent data uploads, the middleware utilizes the LockService mechanism to enforce mutual exclusion during write operations, preventing race conditions and ensuring data integrity. Google Sheets serves as the database, selected for its integration with cloud services. Finally, the user interface is built on the AppSheet no-code platform, which communicates with the backend to

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display real-time sensor status and enables caregivers to input supplementary patient information.

IOT enablement and retrofitting

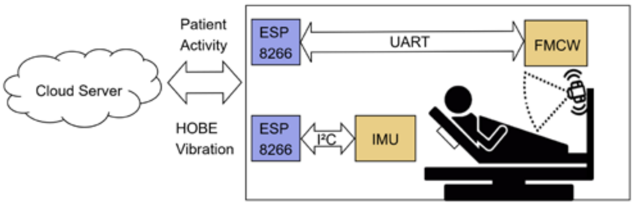

Figure 2 A framework of IoT-enabled nursing care bed.

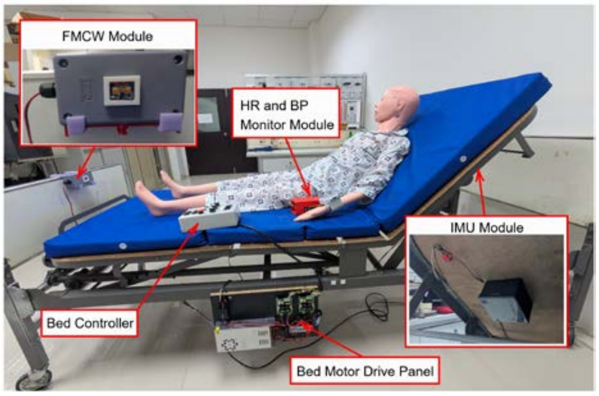

Figure 3 A motor-driven nursing care bed frame with IoT-enabled features.

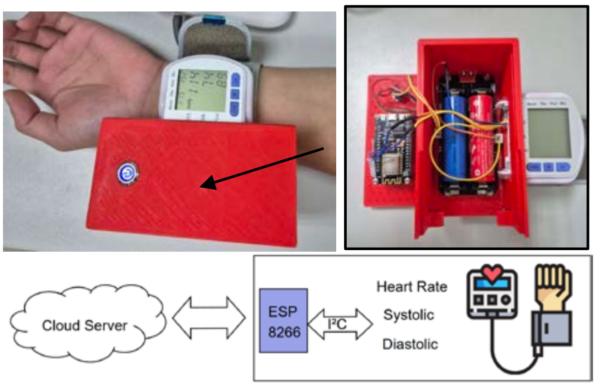

Figure 4 IoT-enabled blood pressure and heart rate monitor.

The first aspect of this study involves the digitalization and IoT enablement of conventional medical devices through targeted hardware and software integration and retrofitting. Retrofitting existing infrastructure with IoT capabilities is a recognized, cost-effective approach for upgrading systems across various sectors [14]. In this study, we focus on enhancing two medical devices to improve caregivers' efficiency. The first device is a smart motor-driven bed modified to provide adjustable head-of-bed elevation (HOBE) and track patient activity, discerning whether they are sitting, lying, or off the bed. An adjustable HOBE is recommended for patients receiving enteral feeding to reduce the risk of aspiration pneumonia and for individuals with certain respiratory conditions to improve oxygenation and ventilation in Positional Obstructive Sleep Apnea (POSA) [15]. The modification process involves retrofitting existing standard motor-driven bedframes with an external IoT-based sensor module. Head of bed elevation (HOBE) monitoring is achieved by retrofitting the existing mechanical structure of the motor-driven bedframe with an Inertial Measurement Unit (IMU) to capture angular orientation and acceleration data to monitor head of bed elevation and patient activity, respectively, as shown in Figure 2. The sensor module is designed and manufactured to be attached to the existing mechanical structure of a motor-driven bed frame as shown on the right of Figure 3. This section of the frame can elevate the patient up to 55°. In this study, MPU6050, a 6-axis sensor that integrates a 3-axis accelerometer and a 3-axis gyroscope on a single chip, is chosen. This combination enables it to measure both linear acceleration and angular velocity, providing comprehensive data on the bed frame's movement and orientation in three dimensions. A key feature is its onboard digital motion processor, which can handle complex sensor fusion algorithms, offloading processing tasks from the main microcontroller and providing more accurate orientation data, especially for HOBE calculations. This module uses a DC 24V power supply from an external power supply, and the IMU communicates with two ESP8266s via the Inter-Integrated Circuit (I^2C) interface, with a sampling time of 10 seconds. Both upload the data to the cloud server through API.

The patient tracking module employs a Frequency-Modulated Continuous-Wave (FMCW) radar sensor. This non-contact technology was chosen because it allows for discrete, continuous monitoring without requiring wearables. This approach enhances patient comfort and is better suited for long-term signal detection compared to contact-based methods [16, 17]. Unlike passive infrared (PIR), which requires significant target motion, the 24GHz FMCW radar detects static presence via micro-Doppler signatures, which are essential for monitoring sleeping patients. Furthermore, it maintains patient privacy by transmitting only anonymized energy metrics, unlike camera-based solutions. The FMCW sensor transmits a continuous chirping signal of slope m during the round trip to the target and back (τ), and the received offset frequency from the one being transmitted during reception initially. This frequency difference is called the Doppler shift or beat frequency (f_b), and it is directly proportional to both the chirp slope and the time delay as $f_b = m \cdot \tau$. Since the time delay is also directly proportional to the target range (R) and the speed of light (c), specifically $\tau = 2R/c$, substituting this into the beat frequency equation reveals a direct relationship between the beat frequency and the target range as $R = (c \cdot f_b)/2m$. Therefore, by measuring f_bThe sensor can detect the presence and position, which affect the

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range and micro-movements of a patient on the bed. In this application, the LD2420, which communicates via a Universal Asynchronous Receiver-Transmitter (UART) interface, is chosen. This 24GHz millimeter wave (mmWave) radar sensor module is specifically designed for human body detection, operates at 3.3V, and offers a configurable detection range of up to 8 meters with a 60° field of view. Raw data is sampled at 0.5-second intervals and smoothed with a 20-sample moving average. The sensor is integrated with an ESP8266, which sends the processed value to a server via UART every 10 seconds. This specific window was selected to mitigate the Head-of-Line blocking and heap fragmentation issues common to ESP8266 SSL/TLS connections. As shown on the left of Figure 3, the module is mounted on the foot side panel of the bed frame and operated with 24 V from an external power supply.

For the second device, an IoT-capable standard heart rate (HR) and blood pressure (BP) monitor, a custom embedded system prototype board was developed, as illustrated in Figure 4. This new board was designed to interface with its internal I²C bus after the monitor itself was modified. Through hardware reverse engineering, the specific data for HR, systolic BP, and diastolic BP were identified. The custom board requests and retrieves this raw physiological data from the controller as an I²C master. After each measurement, the data is then sent to the ESP8266 for processing and handling. Importantly, the original user interface and physical buttons are unaffected and remain fully functional.

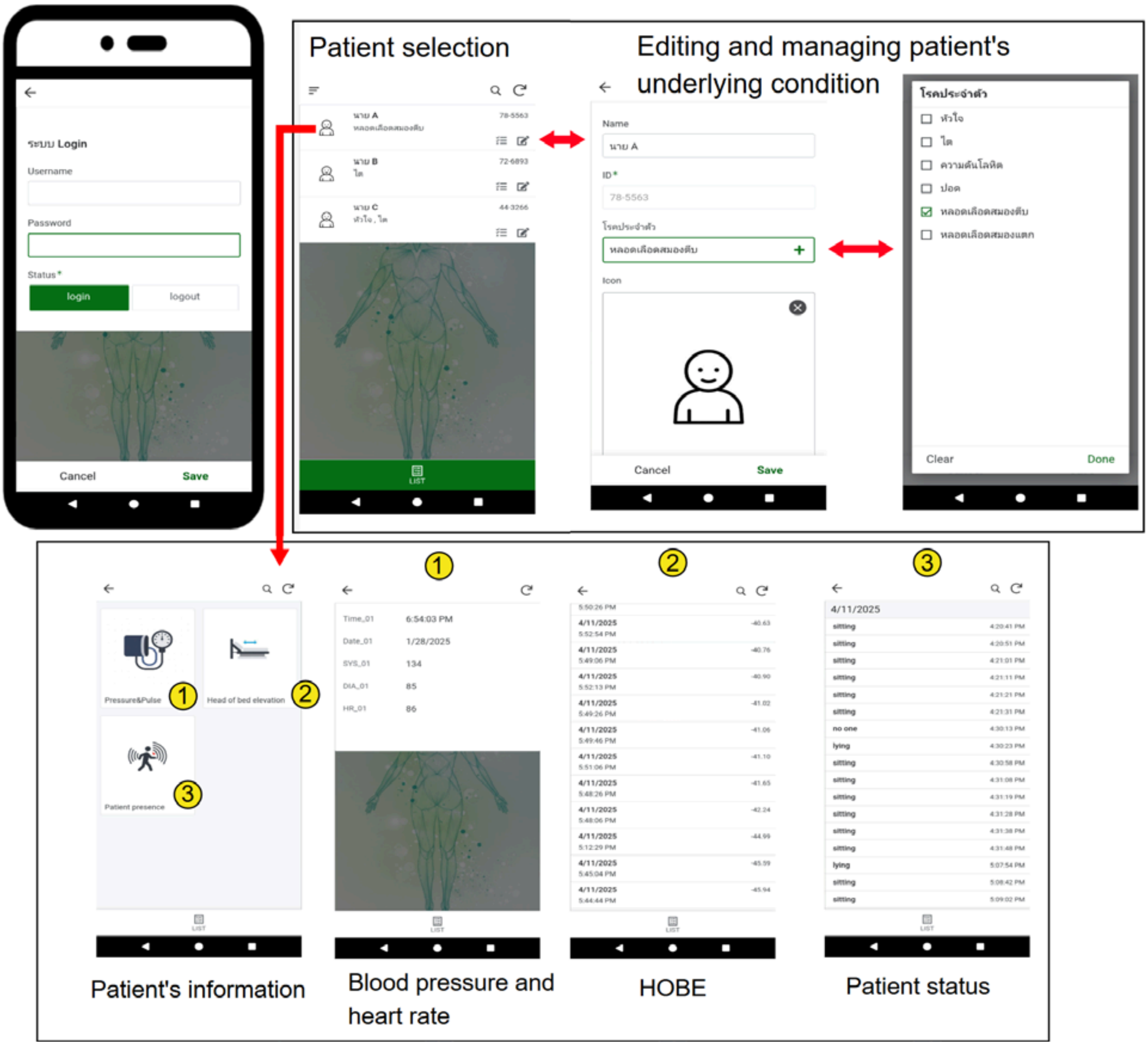

Figure 5 Application Interface.

Application Interface

The application interface is developed entirely on the no-code platform AppSheet. This reduces the costs and technical skills required compared to traditional app development. AppSheet provides a user-friendly mobile interface (Figure 5) that enables caregivers to view patient data and receive alerts remotely. The application begins with a secure login screen that requires a username and password. Once authenticated, users see a primary dashboard listing

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all monitored individuals by name and a unique ID. A key security feature of the application is its implementation of differentiated access levels. Caregivers have a multi-patient view, allowing for broad clinical data in real time. Patients, conversely, are restricted to viewing only their own health records, which fosters transparency and empowers them in their personal health management [18]. This role-based access is crucial for maintaining data privacy. Authorized users can also use the "Edit" icon to manage patient profiles, including updating assigned monitoring devices. Selecting a patient from the list navigates the user to their dedicated profile screen, where Name and ID can be edited. The modifiable field, which represents monitored conditions such as heart disease, kidney complications, or stroke, can be checked or unchecked for each patient. Patient profiles can be appended with extra medical details and monitoring instructions via the *Add* button. Photos can be edited using icons.

The lower section of Figure 5 shows the specific IoT devices connected to specific patients. These tiles provide a direct interface for monitoring device status. The first icon (1) provides a more detailed view of the blood pressure and heart rate data. The second icon (2) indicates the status of the HOBE of the adjustable bed. The last icon (3) indicates whether the patient is detected in bed within the vicinity of a microwave motion sensor. Each data point is labeled with a date and timestamp. On the backend, the data is stored in Google Sheets for each patient's record. Observed timestamp gaps in the third panel indicate scheduled power cycling, confirming auto-initialization and the system's session-based operational model.

RESULTS AND DISCUSSION

The monitoring system successfully integrates IoT capabilities into standard medical devices via retrofitting and includes a no-code application for caregivers. To validate the bedframe's performance, an initial experiment was conducted using the HOBE sensor. Testing was conducted in a noise-controlled environment to isolate sensor response from environmental interference. During the experiment, angle readings from the IMU module were collected and compared against direct measurements from the bedframe. This process was repeated three times at 5° intervals, spanning 0-55°. As shown in Figure 6, the calibration data confirmed that the IMU has high reliability and accuracy. Despite a minor peak error of 2° at 30°, the sensor demonstrated exceptional linearity with a Coefficient of Determination (R^2) of 0.998. The calculated Root Mean Square Error (RMSE) was 0.82°, across the full 0-55°range.

In a second experiment, an FMCW module was evaluated to assess its performance in determining bed status. Distance data was collected for three distinct cases: *Unoccupied*, *Lying*, and *Seated*. A total of 90 measurements were acquired for analysis, with 30 for each case. The analysis revealed complete linear separability in the data, with no overlap between the three class distributions. As a result, a simple statistical thresholding model was computationally sufficient and effective for classifying posture. Decision boundaries were set at the midpoints between the class means, calculated to be 24.83 cm and 72.85 cm, as shown in Figure 7. Upon preliminary evaluation, this method yielded 100% classification accuracy, with a clear distinction between the three cases. This level of performance is significantly better than the 85.9% accuracy of conventional bed exit detection systems [18]. Furthermore, it is comparable to results from other studies, such as 99.8% accuracy from infrared arrays [19] and 98.6% from other 24 GHz radar systems [20]. This efficient approach provides maximal accuracy with minimal model complexity, making it the ideal solution for this application.

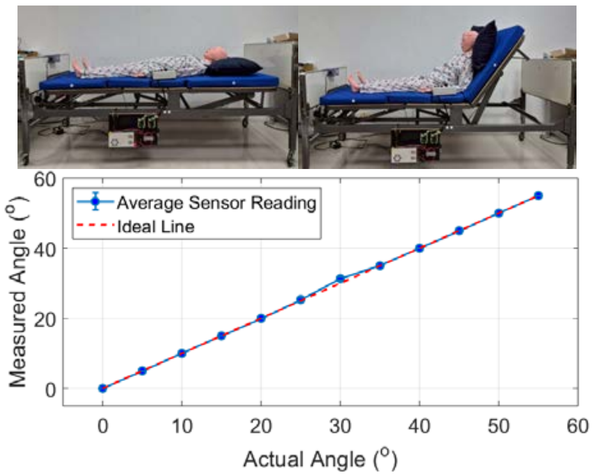

Figure 6 Calibration data of the HOBE from 0° to 55°.

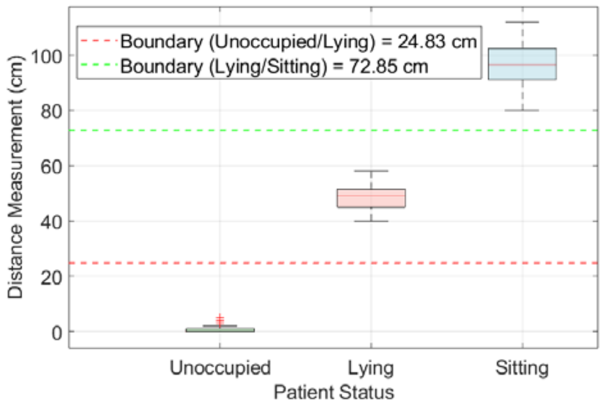

Figure 7 Classification results of patient status using the statistical method.

To assess the power consumption of both devices, a Fluke 117 multimeter was used to compare the current draw with their IoT functionalities enabled versus disabled. The IoT Bed device exhibited an idle power consumption of 1.09 W, which decreased to

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0.86 W when its IoT functionality was turned off. This overall power usage is in line with other recent studies, such as a radar-based system, which reported an idle consumption of 1.2 W [22]. This highlights the power contribution from the smart features; notably, the FMCW component was the most significant power consumer, accounting for 63.6% of the total energy usage. Table 1 summarizes the power consumption of the second device, comparing its IoT-disabled version with our modified IoT-enabled variant across the following operational modes: *Idle*, *Pump*, *Measure*, and *Upload*. The data reveals a more nuanced picture. While the idle current is slightly higher for the IoT version, the active states (*Pump* and *Measure*) also show increased power consumption, suggesting that the concurrent integration of sensing, processing, and network connectivity demands more power.

Based on the findings, the developed system offers a practical and effective solution to enhance patient care management. Both the HOBE sensor and FMCW bed occupancy sensor module in the bed device demonstrated high accuracy and repeatability. These results validate that retrofitting standard medical devices with IoT capabilities is a practical and effective solution for patient care management. It presents a cost-effective method for healthcare providers to modernize equipment without a financially prohibitive overhaul. However, a critical trade-off exists: valuable real-time monitoring and alert features come at the cost of increased power consumption. The higher energy use in both idle and active modes of IoT-enabled devices underscores the significant demands of sensing, processing, and connectivity. This balance between advanced functionality and power efficiency is a fundamental consideration for deploying such systems, particularly for battery-dependent devices in resource-constrained environments.

Table 1 Current consumption of blood pressure and heart rate monitor.

State	Idle (A)	Pump (A)	Measure (A)	Upload (A)
IoT-disabled	0	0.27	0.11	N/A
IoT-enabled	0.06	0.35	0.18	0.07

Unlike local alarm systems (e.g., Zigbee or LoRa), the current architecture relies on stable WiFi connectivity and cloud availability. While the system implements a 10-second buffer to mitigate minor fluctuations, a complete network outage would interrupt real-time alerts, necessitating a fail-safe local buzzer for critical deployments. Furthermore, the statistical thresholding model used for the FMCW radar could potentially trigger false alarms in real-world use, suggesting the need for more advanced machine learning classifiers in complex ward environments. While the 60° field of view covers the standard bed area, extreme edge-of-bed movements may fall outside the sensor's detection cone.

A comparative cost-benefit analysis reveals economic advantages of the proposed retrofit approach over commercial monitoring systems. The total implementation cost per patient station ($100-175, based on 2024-2025 component pricing for ESP8266 microcontrollers and sensors commonly used in low-cost IoT healthcare applications) represents a 67-85% cost reduction compared to commercial RPM systems, which range from $275-$7,963 per patient annually for elderly chronic disease monitoring [23]. This cost reduction aligns with established frugal innovation precedents in healthcare, which prioritize systematic simplification and the use of low-cost technology components while maintaining clinical efficacy [24]. The system achieves rapid payback by preventing costly adverse events. This economic model demonstrates that retrofitting existing medical infrastructure can provide RPM services accessible to resource-constrained healthcare facilities serving aging populations.

To transition this system from a functional prototype to a scalable and secure production deployment, a robust data management and privacy strategy is essential. The critical first step involves migrating the backend to a managed relational database, such as Google Cloud SQL, to handle high volumes of real-time patient data. To maintain system performance within the Google Sheets ecosystem prior to a complete SQL migration, an automated archiving script can be implemented. This routine would periodically migrate historical data to cold storage, such as csv files. This production architecture must explicitly align with the Personal Data Protection Act (PDPA) in Thailand. To meet these stringent security requirements, patient data would be encrypted at the application level using Google Cloud Key Management Service (KMS). The backend would request encryption via the KMS API, ensuring that raw keys are never exposed and providing an auditable process for data protection.

This strategy of repurposing existing medical hardware with low-cost IoT technology creates a powerful model for technological sustainability, directly aligning with key UN Sustainable Development Goals. It embodies SDG 9 (Innovation and Infrastructure) by sustainably upgrading existing assets rather than requiring costly replacement. This innovation, in turn, serves SDG 3 (Good Health and Well-Being) by enhancing access to healthcare and proactive monitoring for Thailand's elderly population. Furthermore, the approach supports SDG 12 (Responsible Production and Consumption) by extending the functional life of medical devices, thereby minimizing potential e-waste and promoting a more circular economy in healthcare.

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CONCLUSIONS

This paper presents an IoT-based remote monitoring system designed to enhance caregiver effectiveness through retrofitting smart sensors with a no-code application. The system integrates a smart bed monitoring patient movement and HOBE, and an IoT-enabled blood pressure/heart rate monitor. Data is transmitted wirelessly to a cloud database, with real-time visualization via a mobile application that features differentiated access controls. Validation showed high accuracy for the HOBE sensor (maximum error of 2°) and 100% classification accuracy for the FMCW occupancy sensor under controlled settings. Power analysis revealed significant energy overhead from IoT enablement, with idle consumption increasing from 0.86 W to 1.09 W, where the FMCW sensor consumed 63.6% of total power. The blood pressure monitor showed increased consumption during active states, confirming that concurrent sensing, processing, and connectivity are power-intensive. This case study provides insights into the practicalities of IoT integration in healthcare and enables future compatibility with additional medical devices. While the current study validates the technical accuracy and power efficiency of the system, future work will focus on a clinical usability study with nursing staff to evaluate the user experience of the no-code interface in a live ward setting.

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