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Article

Design and Development of a Cloud-Based Student Accommodation Management Application

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Abstract

The rapid growth in student populations across higher institutions has intensified the challenges associated with managing student accommodation, particularly in environments where traditional, manual, or semi-digital systems are still in use. These conventional approaches are often inefficient, prone to errors, lack transparency, and fail to provide real-time access to critical housing information for students, landlords, and administrators. This project focuses on the design and development of a cloud-based student accommodation management application aimed at addressing these limitations through a centralized, scalable, and user-friendly digital platform. The proposed system leverages cloud computing technologies to enable seamless access to accommodation data anytime and from any location, thereby improving availability, reliability, and system performance. Key functionalities of the application include student registration and authentication, accommodation listing and search, room allocation, booking management, payment tracking, maintenance reporting, and administrative oversight. By automating these processes, the system reduces administrative workload, minimizes data redundancy, and enhances decision-making through real-time data synchronization and analytics. From a user-experience perspective, the application is designed to prioritize simplicity, accessibility, and responsiveness, ensuring that students can easily locate suitable housing while accommodation managers can efficiently monitor occupancy status and manage resources. The cloud-based architecture further ensures data security, scalability, and fault tolerance, making the system adaptable to institutions of varying sizes. Overall, the developed application demonstrates how cloud-based solutions can significantly improve the efficiency, transparency, and effectiveness of student accommodation management. The study highlights the potential of modern web and cloud technologies in transforming traditional campus housing systems into intelligent, reliable, and student-centered digital services.

Keywords: cloud computing; student housing management; SaaS; usability testing; User Acceptance Testing (UAT)

1. Introduction

1.1. Background of the Study

The digital transformation of higher education infrastructure is a fundamental requirement for addressing the logistical complexities of modern campus life. Student accommodation management, a critical service that directly influences student well-being and institutional efficiency, has historically relied on localized, fragmented legacy systems. These traditional frameworks often suffer from limited interoperability and a lack of real-time data synchronization, which results in significant administrative bottlenecks [1]. As university enrollments continue to rise globally, the pressure on housing departments to provide transparent, efficient, and accessible services has intensified.

Cloud computing has emerged as the definitive solution to these infrastructural challenges by offering a scalable, on-demand delivery model for computing resources. The transition from on-

premise hardware to **Software-as-a-Service (SaaS)** models allows institutions to leverage high-availability clusters and distributed databases, ensuring that services remain operational even during periods of peak demand [2]. However, the technical migration to the cloud is only one aspect of a successful system; the human-centric design of these platforms is equally vital. Recent advancements in the field highlight that the efficacy of cloud-native housing portals is primarily validated through rigorous **Usability and User Acceptance Testing (UAT)**, ensuring that the software aligns with the diverse needs of the student population [3].

1.2. Problem Statement

Despite the availability of generic property management software, specialized student housing remains underserved by current technological offerings. Existing systems frequently exhibit the following deficiencies:

1. **Inelastic Infrastructure:** Most legacy portals lack the horizontal scalability required to manage the surge of concurrent users during peak registration windows, leading to frequent system failures [4].
2. **Fragmented User Experience:** Students are often forced to navigate multiple, disconnected platforms for room selection, lease execution, and financial transactions, which increases the likelihood of user error and abandonment.
3. **Manual Resource Allocation:** The absence of intelligent automation in roommate matching and inventory management forces administrators to perform manual data entry, which is both time-consuming and prone to human error [1].
4. **Security and Compliance Gaps:** Many older systems do not meet contemporary standards for data encryption and privacy, such as GDPR or SOC2, placing sensitive student information at risk [5].

A critical need exists for a unified, cloud-based application that integrates these disparate functions into a single, secure, and user-friendly ecosystem.

1.3. Objectives of the Research

The primary goal of this research is the design, implementation, and validation of a cloud-native student accommodation management system. To achieve this, the study pursues the following specific objectives:

- **To Engineer a Scalable Cloud Architecture:** Develop a multi-tier system using containerized microservices to ensure fault tolerance and high performance [2].
- **To Implement an Integrated Student Portal:** Design a "mobile-first" interface that facilitates real-time room booking, digital contract management, and secure payment processing.
- **To Develop an Administrative Command Center:** Create a centralized dashboard for housing officers to monitor occupancy rates, manage maintenance workflows, and generate financial reports.
- **To Conduct Empirical User Validation:** Apply a standardized testing framework to evaluate the system's usability and ensure it meets the criteria for student and staff acceptance [3].

1.4. Research Questions

This study addresses several key questions regarding the intersection of cloud engineering and student services:

1. How can cloud-native load balancing and auto-scaling be utilized to mitigate system latency during high-traffic enrollment periods?
2. What architectural patterns best support the security and integrity of financial and personal data in a multi-tenant housing environment [4]?
3. How do usability factors and interface design influence the adoption rate of new housing technologies among international student cohorts [3]?

1.5. Significance of the Study

The outcomes of this research provide a technical and operational blueprint for the modernization of student housing. For academic institutions, the study demonstrates how to reduce operational expenditure (OPEX) by transitioning from costly on-premise servers to optimized cloud environments. For the student body, the proposed application removes barriers to entry, providing a transparent and efficient mechanism for securing essential housing. Furthermore, by incorporating the testing methodologies outlined in [3], this research contributes to the broader academic discourse on **Human-Computer Interaction (HCI)** within the context of enterprise cloud applications.

1.6. Scope and Delimitations

This research focuses specifically on the development of the cloud-based application layer and the associated database management systems. While the study addresses integration with third-party payment gateways, it does not involve the creation of new financial protocols. The user testing phase is delimited to a representative sample of undergraduate and postgraduate students to ensure the findings are applicable to the primary user demographic.

2. Literature Review

2.1. Theoretical Framework of Cloud Computing

Cloud computing has redefined the delivery of information technology services by abstracting physical hardware into virtualized, scalable resources. This paradigm is characterized by five essential traits defined by the National Institute of Standards and Technology (NIST): on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service [7]. In the context of student accommodation, these features allow for a dynamic response to the cyclical nature of university housing demands, where system load varies significantly between peak enrollment periods and academic hiatuses.

The architecture of modern accommodation applications typically utilizes three service models: **Infrastructure as a Service (IaaS)**, **Platform as a Service (PaaS)**, and **Software as a Service (SaaS)** [2]. Current trends in 2024 and 2025 indicate a significant shift toward SaaS-based property management systems (PMS) due to their low entry barriers and high interoperability with other campus systems, such as student information portals and financial billing modules [1].

2.2. Evolution of Student Housing Management Systems

Historically, housing management relied on localized database systems that required manual intervention for room assignments and lease tracking. These systems were often plagued by data redundancy and lacked the capacity for real-time updates [1]. The emergence of web-based applications introduced centralized management; however, they remained constrained by fixed server capacities.

Research in 2025 highlights that modern systems are now moving toward "**Hyper-digital**" environments, incorporating mobile-first strategies and IoT-enabled features such as keyless entry and smart energy monitoring [8]. This shift is driven by the expectations of "Gen Z" students who prioritize digital self-service, instant communication, and 24/7 accessibility [4]. Consequently, the integration of automated roommate matching and real-time maintenance dashboards has become a standard requirement for competitive housing platforms.

2.3. User Acceptance and Usability Engineering

The technical superiority of a cloud application does not guarantee its institutional success. The "Human-Computer Interaction" (HCI) aspect remains a critical determinant of system adoption. Usability engineering focuses on reducing the cognitive load of students who may be navigating the housing process under significant stress [3].

Ref. [3] S. Penmetsa highlights that **User Acceptance Testing (UAT)** for cloud-based student housing applications must go beyond functional verification; it must address the perceived ease of use and the trustworthiness of the platform [3]. In a study involving student accommodation platforms, it was found that usability issues in the application phase were directly correlated with high abandonment rates. Therefore, implementing standardized usability scales and feedback loops during the development phase is essential to ensure that the final product meets the diverse needs of an international student body [9].

2.4. Security and Privacy in the Cloud

The migration of student data to the cloud introduces complex security challenges, particularly regarding the storage of personally identifiable information (PII) and financial records. Academic institutions are subject to rigorous data protection regulations, such as the General Data Protection Regulation (GDPR) and similar local frameworks [10].

Recent literature advocates for the adoption of **Zero Trust Architecture (ZTA)** in educational cloud services. Unlike traditional perimeter-based security, Zero Trust operates on the principle of "never trust, always verify," which is particularly effective in mitigating unauthorized access to sensitive housing databases [11]. Furthermore, modern cloud platforms utilize advanced encryption-at-rest and in-transit protocols to protect student financial data during rent transactions [5].

2.5. Software Performance and DevOps Integration

The modernization of student housing platforms necessitates a focus on the speed and reliability of software delivery. According to the research conducted by Forsgren, Humble, and Kim, the implementation of **Continuous Integration and Continuous Deployment (CI/CD)** is a primary predictor of high organizational performance in software engineering [11]. Their work, *Accelerate*, provides a framework for measuring system stability through deployment frequency and mean time to recovery (MTTR), which are critical metrics for maintaining cloud-based accommodation systems during high-traffic windows.

2.6. Summary of Literature

The consensus in the literature suggests a clear trajectory toward cloud-native, SaaS-based solutions for student accommodation. While the scalability and efficiency of the cloud are well-documented by Erl [10] and Buyya [2], the success of these systems hinges on a balanced approach that synthesizes robust cloud architecture with the human-centric usability testing emphasized by Penmetsa [3] and the performance benchmarks established in the *Accelerate* study [11].

3. Research Methodology

3.1. Research Design and Framework

The development of the Cloud-Based Student Accommodation Management Application follows an **Agile Software Development Life Cycle (SDLC)**. This iterative approach was selected to allow for continuous integration and the flexibility to address evolving user requirements during the development process. Unlike traditional Waterfall models, the Agile framework facilitates rapid prototyping, ensuring that the final system is both technically robust and user-aligned [1].

The methodology is divided into four primary phases: Requirements Engineering, System Architecture Design, Implementation (Coding), and Empirical Validation through User Acceptance Testing (UAT).

3.2. Requirements Engineering

Requirements were gathered through a mixed-methods approach involving stakeholder interviews and a comparative analysis of existing property management tools.

- **Functional Requirements:** These include automated room allocation, digital lease management, real-time maintenance ticketing, and secure payment processing.
- **Non-Functional Requirements:** Prioritization was given to **scalability**, ensuring the system can handle concurrent users; **security**, protecting student PII; and **usability**, as emphasized in the research by S. Penmetsa [3].

3.3. System Architecture and Design

The application utilizes a **Cloud-Native Microservices Architecture** to ensure independent deployability and fault isolation. The system is decomposed into distinct services (e.g., User Service, Booking Service, Payment Service) that communicate via RESTful APIs.

- **Frontend Layer:** Developed using the React.js framework to provide a responsive, "mobile-first" experience.
- **Backend Layer:** Built on a Node.js/Express environment, facilitating high-concurrency handling through non-blocking I/O operations.
- **Database Layer:** A hybrid approach is utilized, employing PostgreSQL for relational data (leases, financial records) and MongoDB for unstructured data (maintenance logs and user activity) [4].
- **Cloud Infrastructure:** The system is hosted on a major cloud provider (e.g., AWS), utilizing Elastic Load Balancing (ELB) and Auto-Scaling groups to maintain performance during peak traffic [12].

3.4. Data Flow and Logic

The application's logic is represented through comprehensive **Data Flow Diagrams (DFD)** and **UML Sequence Diagrams**. These diagrams illustrate the path of a student's request from the initial room search through to the final lease execution and deposit payment. This structured design phase ensures that data integrity is maintained across all cloud nodes.

3.5. Development and Testing Environment

The implementation phase utilizes **DevOps** principles, including Continuous Integration and Continuous Deployment (CI/CD) pipelines. This allows for automated testing of code commits to identify vulnerabilities or bugs early in the cycle [11].

- **Unit Testing:** Individual components are tested to ensure logical correctness.
- **Integration Testing:** Verifies that the cloud services communicate effectively without data loss.
- **User Acceptance Testing (UAT):** Following the methodology prescribed by Penmetsa [3], a cohort of 50 students and 10 administrative staff members was selected to evaluate the system. The testing focused on "System Usability Scales" (SUS) to quantify user satisfaction and identify friction points in the housing application process.

3.6. Ethical Considerations

As the application handles sensitive student data, ethical considerations were paramount. The research design incorporates "Privacy by Design" principles, ensuring all data is anonymized during the testing phase and encrypted using AES-256 standards in production environments [5]. Informed consent was obtained from all participants involved in the UAT phase.

4. Results and Discussion

4.1. System Implementation Overview

The development phase culminated in a fully functional, cloud-native student accommodation management application. The system was deployed on a distributed cloud infrastructure, utilizing

container orchestration to manage microservices. Preliminary stress tests indicated that the architecture successfully maintained sub-second latency even under simulated loads of 500 concurrent users, validating the scalability of the chosen SaaS model [2].

4.2. Performance Metrics and Scalability Analysis

To evaluate the technical efficiency of the cloud-based system, several Key Performance Indicators (KPIs) were monitored during the pilot phase. These included server response time, database query latency, and resource utilization during peak traffic.

- **Latency Management:** Through the implementation of a Content Delivery Network (CDN) and edge caching, the average page load time was reduced to 1.2 seconds, a 65% improvement over the institution's previous legacy system.
- **Database Throughput:** The hybrid use of PostgreSQL and MongoDB allowed for high-speed retrieval of room availability data while maintaining ACID compliance for financial transactions [4].
- **Auto-Scaling Efficiency:** During a simulated "housing rush," the system's auto-scaling group successfully provisioned additional compute instances within 180 seconds of CPU utilization exceeding the 70% threshold, preventing any service downtime [12].

4.3. User Acceptance Testing (UAT) Results

Following the framework established by S. Penmetsa, the application underwent rigorous User Acceptance Testing to determine its viability in a real-world academic environment [3]. A total of 60 participants (50 students and 10 administrators) evaluated the system based on the System Usability Scale (SUS).

4.3.1. Student Feedback

The student cohort reported high levels of satisfaction with the "mobile-first" interface. Key findings included:

- **Ease of Navigation:** 92% of students successfully completed the room booking and lease execution process in under five minutes without external assistance.
- **Perceived Trust:** The integration of secure, transparent payment gateways led to a high degree of confidence in the platform's handling of financial data [3].

4.3.2. Administrative Efficiency

Administrative staff utilized a centralized dashboard to manage inventory and track maintenance requests. The results showed a 40% reduction in time spent on manual room assignments compared to previous semesters. The automated roommate matching algorithm was cited as the most significant contributor to administrative time savings.

4.4. Discussion of Findings

The results confirm that a cloud-native approach addresses the core deficiencies of traditional housing software. The elasticity of the cloud ensures that institutions no longer need to over-provision hardware for short-term peak periods, leading to a more cost-effective operational model [5].

Furthermore, the study validates the assertion by Penmetsa that usability is the primary driver of user acceptance in educational cloud tools [3]. While technical robustness (such as uptime and security) is essential, the "Human-Computer Interaction" (HCI) layer determines whether the system is embraced or resisted by the student body. The high SUS scores obtained in this study suggest that a user-centric design approach, coupled with iterative feedback loops, is necessary for the successful rollout of campus-wide digital transformations [14].

4.5. Comparison with Existing Solutions

In comparison to off-the-shelf property management software, the developed application provided superior integration with university-specific APIs (such as student ID verification and financial aid systems). This localized customization, hosted on a global cloud infrastructure, represents a significant advancement in specialized ERP solutions for higher education.

5. Conclusions and Recommendations

5.1. Conclusions

The research successfully executed the design and development of a cloud-native student accommodation management application, addressing the critical gaps identified in legacy housing systems. By leveraging a **Software-as-a-Service (SaaS)** architecture, the study demonstrated that cloud-based platforms offer the necessary elasticity to manage the volatile traffic patterns characteristic of the academic calendar. The system's ability to maintain high performance under concurrent load, as detailed in Chapter 4, confirms that microservices and containerized environments are superior to monolithic, on-premise configurations for campus logistics [2,12].

Furthermore, the study confirms that technical robustness is insufficient without a focus on the end-user. Following the principles established by S. Penmetsa, the integration of **User Acceptance Testing (UAT)** and usability metrics proved that a user-centric design significantly reduces the administrative burden and improves student engagement [3]. The high adoption rates observed during the pilot phase suggest that digital transparency in room allocation and financial management is no longer a luxury but a requirement for modern higher education institutions.

5.2. Contributions to Knowledge

This research provides several key contributions to the field of educational technology and cloud engineering:

- **Architectural Blueprint:** Provides a validated framework for deploying multi-tenant housing applications using modern cloud-native stacks.
- **Methodological Validation:** Reinforces the necessity of iterative usability testing in specialized ERP systems, specifically within the student housing sector [3].
- **Operational Efficiency:** Quantifies the reduction in administrative overhead achieved through automated roommate matching and digital lease management.

5.3. Recommendations for Implementation

For institutions seeking to adopt this or similar systems, the following recommendations are provided:

1. **Hybrid Cloud Strategy:** Institutions with existing legacy databases should consider a hybrid cloud approach to ensure data continuity during the migration phase [15].
2. **Continuous Feedback Loops:** As student demographics and technical habits evolve, the system should undergo biennial usability audits to maintain high acceptance levels [3].
3. **Security Hardening:** Regular penetration testing and adherence to Zero Trust principles are essential to protect the integrity of student PII and financial records in a shared cloud environment [5].

5.4. Future Work

While the current application addresses immediate logistical needs, future research should explore the integration of **Artificial Intelligence (AI)** and the **Internet of Things (IoT)**:

- **Predictive Maintenance:** Utilizing machine learning algorithms to predict facility failures based on historical maintenance logs.

- **Smart Dormitories:** Integrating IoT sensors for automated energy management and smart access control, which can be managed directly through the cloud interface.
- **Enhanced Matching Algorithms:** Using deep learning to refine roommate matching based on more complex psychological and behavioral profiles.

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