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Integration of Mobile Computing and Cloud Computing in Healthcare

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Abstract

Background: The integration of mobile computing and cloud computing has the potential to revolutionize healthcare delivery by providing ubiquitous access to resources and enabling new service development and delivery models. While cloud computing has been extensively studied in fields such as genomics and molecular medicine, its application in healthcare beyond these domains remains relatively unexplored. This scoping review aims to identify the current state and emerging research topics in cloud computing in healthcare outside of the traditional "OMICS context." **Methods:** A comprehensive search was conducted in MEDLINE in July 2013 and December 2014 using keywords related to cloud computing and cloud-based services. The identified journal and conference articles were independently categorized and summarized by two researchers, who subsequently consolidated their findings. **Results:** A total of 102 publications were analyzed, revealing six main topics in cloud computing in healthcare: telemedicine/teleconsultation, medical imaging, public health and patient self-management, hospital management and information systems, therapy, and secondary use of data. Common features utilized in these applications included broad network access for data sharing and access, as well as rapid elasticity to meet computing demands. While some articles highlighted the cost-effectiveness of pay-per-use cloud services, only 14 articles reported successful implementations, with many publications focusing on conceptual or prototypic projects. Additionally, several articles equated cloud computing with internet-/web-based data sharing, failing to illustrate the unique benefits of the cloud computing paradigm. **Conclusions:** Although the integration of mobile computing and cloud computing in healthcare is gaining attention, successful implementations in the field are still limited. Many papers use the term "cloud" interchangeably with "virtual machines" or "web-based" without clearly demonstrating the advantages of the cloud paradigm. Data safety and security concerns associated with involving external cloud partners remain significant barriers to

adoption in the healthcare domain. As of now, cloud computing is primarily favored for its individual features, such as elasticity, pay-per-use models, and broad network access, rather than as a comprehensive cloud computing paradigm.

Keywords

Mobile Computing, Cloud Computing, Healthcare, Telemedicine, Medical Imaging, Data Security, Artificial Intelligence, Healthcare Delivery, Clinical Decision Support, Predictive Modeling

1. Introduction

The integration of mobile computing and cloud computing in the healthcare industry holds great potential for transforming healthcare delivery and improving patient outcomes. The power of mobile computing, cloud computing, and AI in healthcare is only beginning to be realized (Naseem et al., 2020). Mobile healthcare applications, such as electronic health records (EHRs) that allow users to access their information from any location via mobile devices have already provided several tangible benefits. These applications have significantly improved patient safety through real-time data sharing and instant access to medical records and metrics. The applications have also allowed for the creation of care plans based on real-time data from patients' independent systems (such as, home monitoring systems, wearable devices) and collaborative systems (such as, electronic health records), resulting in efforts to improve the quality of life for patients suffering from neurological disorders such as Parkinson's diseases. This introduction aims to provide a comprehensive overview of the importance and significance of this integration, along with the current state of research in the field.

Over the years, advancements in mobile computing and cloud computing technologies have revolutionized various industries, and healthcare is no exception. The technologies offer opportunities to improve accessibility, efficiency, and quality of healthcare services (Majeed & Hwang, 2022). The integration of mobile computing and cloud computing can leverage the power of Fast Healthcare Interoperability Resources (FHIR) and artificial intelligence (AI) to unlock new possibilities. FHIR provides a standardized framework for exchanging healthcare data, while AI offers advanced analytics, predictive modeling, and clinical decision support (Asan & Choudhury, 2021). In this manuscript, various healthcare applications of FHIR and AI are discussed across three different use cases, including clinical decision support, predictive modeling, and improvements in patient safety (Mbunge & Muchemwa, 2022; Chattu, 2021). This manuscript highlights the benefits, challenges, and considerations associated with the integration of mobile computing, cloud computing, and AI in healthcare (Gastounioti et al., 2022). This manuscript also discusses the potential for revo-

lutionizing healthcare delivery through AI-powered analytics tools that process and analyze structured FHIR data. Despite the promising potential, there are still challenges and controversies surrounding the integration of these technologies in healthcare. Issues such as data security, privacy concerns, interoperability, and ethical considerations need to be carefully addressed to ensure the responsible and effective implementation of mobile computing and cloud computing in healthcare. Therefore, the study aims to contribute to the existing body of knowledge by providing insights into integrating mobile computing and cloud computing in healthcare.

2. Materials and Methods

To conduct the review on the integration of mobile computing and cloud computing in healthcare, the researcher used a systematic literature review. The systematic approach comprised different stages.

2.1. Literature Search

A comprehensive search was performed using the MEDLINE and Google Scholar databases to collect relevant publications. The search terms were optimized to include both mobile computing and cloud computing, as well as research publications that involved the term healthcare. The keywords used for the MEDLINE search included mobile devices, mobile Día, healthcare, healthcare informatics, health informatics, healthcare system, and health service. The keyword used for the Google Scholar search was mobile computing and cloud computing. The following combinations of keywords were used in each database search: "mobile computing" AND "cloud computing," "cloud computing" AND "healthcare," "healthcare" AND "health information systems," and "health information systems" AND "mobile device." Publications that did not contain the identified key terms were excluded from the study. The search terms used were specifically related to the topic of integration of mobile computing and cloud computing in healthcare.

2.2. Relevance Screening

In the initial screening, the retrieved publications were evaluated for their relevance based on the title, abstract, keywords, and type of publication. The final set of publications was selected based on the following criteria: relevance, relevance to the topic, and significance. If a publication was found to be relevant to the topic, it was excluded from further analysis (such as., if a publication dealt with mobile computing-based healthcare applications but did not consider cloud computing in its details). Papers that were clearly unrelated or focused on cloud computing in non-healthcare domains were excluded.

2.3. Review and Summarization

The remaining publications were thoroughly reviewed by a team of researchers

with expertise in medicine, computer science, medical informatics, and statistics. References and abstracts were scanned manually to identify relevant papers that could be included in the review. The highest-scoring papers were selected for final analysis. Each paper was independently reviewed by two reviewers, and any conflicts were resolved through consensus discussions. The review focused on extracting relevant information regarding the integration of mobile computing and cloud computing in healthcare.

2.4. Data Extraction

A structured data extraction form was used to collect key information from eligible publications. The extracted data included conceptual information (including., categories, definitions, and applications), methodological and empirical details (including., key findings, limitations, discussion of challenges, and recommendations), and implementation details (including., technology implementation examples). Each paper was reviewed multiple times to capture all relevant information that might have been missed during the initial screening. The form included closed and open-ended questions to capture details such as the state of the described cloud computing system (theoretical, conceptual, prototype, or successful), the target users (physicians, patients, researchers), the cloud provider (proprietary or commercially hosted solutions), and the mention of essential cloud computing characteristics (self-service, broad network access, resource pooling, rapid elasticity, and measured service) as defined by NIST. Additionally, advantages, challenges, security concerns, cost considerations, specific usage of cloud computing, and the definition of cloud computing were also recorded.

3. Results

Integrating mobile computing and cloud computing in healthcare facilitated real-time access to patient data, seamless communication, and remote monitoring, it enabled data to be stored in cloud storage, accessed in the cloud, and accessed via mobile devices (Friedrich et al., 2021). Mobile computing and cloud computing have already provided several tangible benefits. These applications have significantly improved patient safety through real-time data sharing and instant medical records and metrics access.

The applications have also allowed for the creation of care plans based on real-time data from patients' independent systems, such as home monitoring systems or collaborative systems, including electronic health records. These efforts have improved the quality of life for patients suffering from neurological disorders such as Parkinson's disease. Healthcare providers can access electronic health records (EHRs) and exchange health information efficiently through mobile devices and cloud platforms. This integration enhanced the accessibility and availability of patient data, leading to improved decision-making and streamlined healthcare processes.

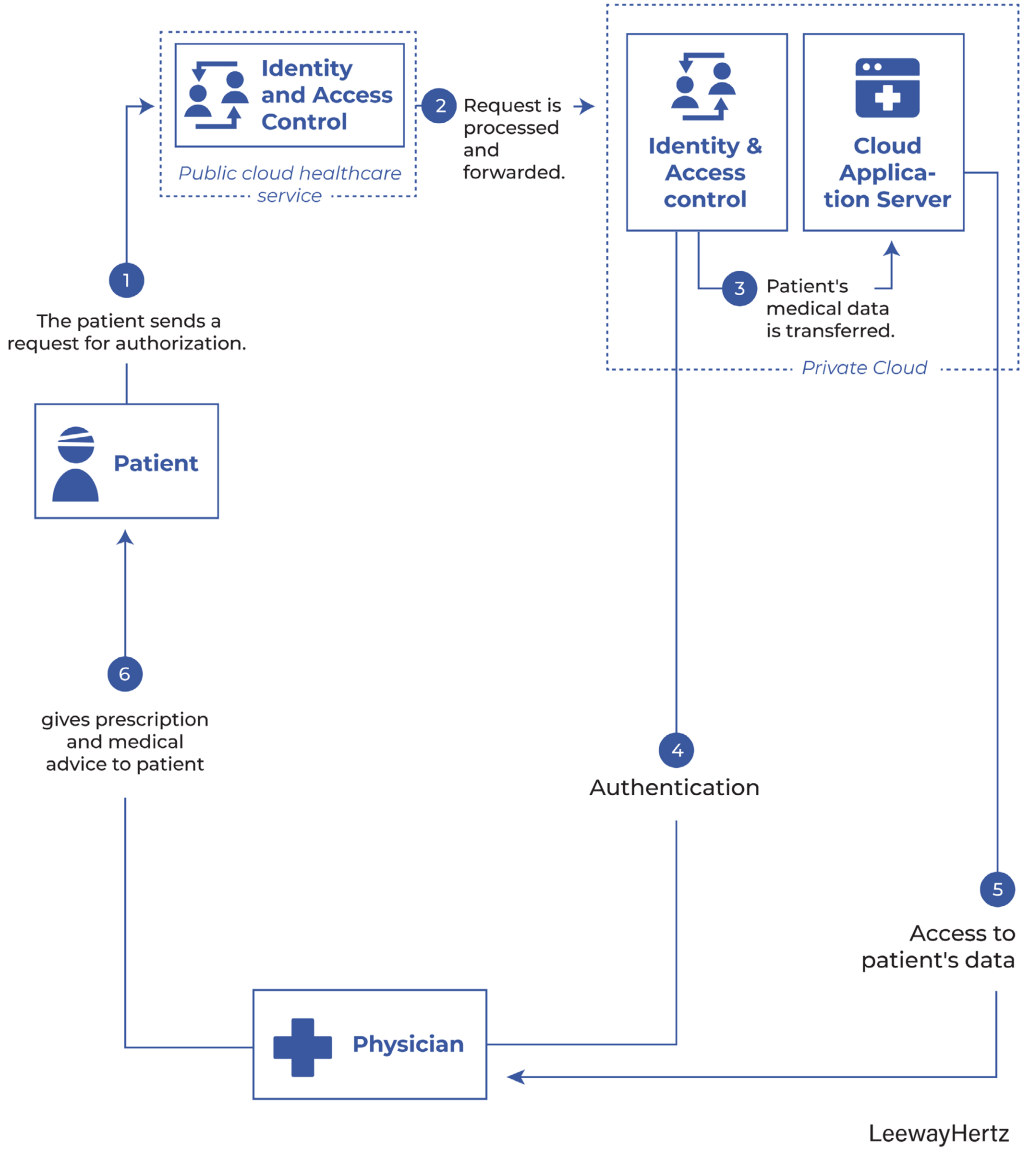

Figure 1. Showing cloud computing services used in healthcare (Takyar, 2023).

Figure 1 is showing Cloud-based architecture and it will give a complete idea of the overall workflow process. The workflow of the cloud services is presented from the perspective of private and public cloud communication scenarios. Private cloud platform includes hardware and software components that address all identified healthcare requirements and the essential functionalities involved in this workflow are authentication, authorization, data persistence, data integrity and data confidentiality.

3.1. Leveraging Fast Healthcare Interoperability Resources (FHIR)

The utilization of Fast Healthcare Interoperability Resources (FHIR) provided a standardized framework for exchanging healthcare data. This facilitated data interoperability and seamless integration between different healthcare systems

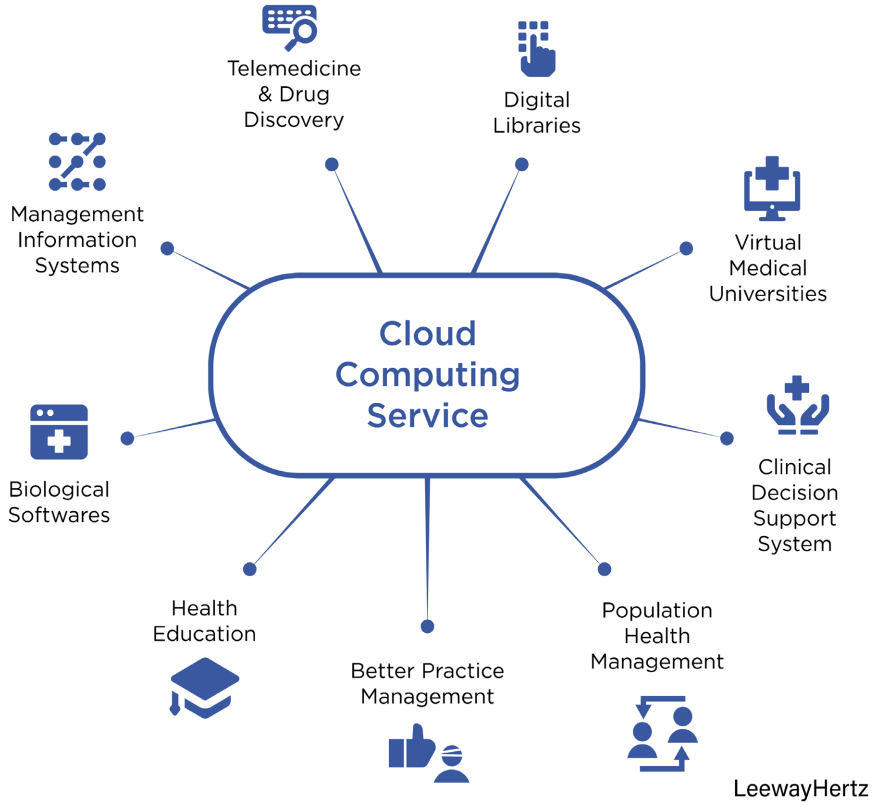

Figure 2. Showing the way healthcare can leverage the importance of cloud computing in healthcare (Takyar, 2023).

and applications (Ullah et al., 2020). FHIR provided a common framework that could support the sharing and integration of healthcare data among diverse systems.

It simplified the data exchange process, which could lead to higher scalability, increased efficiency, and reduced costs. Moreover, the frameworks incorporated security protocols and standardized interfaces to ensure data accuracy and privacy protection. It provided extensive metadata to characterize complex Healthcare Terminologies (HCXML) schemas to facilitate the discovery and understanding of inter-system relationships (Bajwa et al., 2021). Implementing FHIR enabled sharing of structured health data, such as patient demographics, vital signs, lab results, and medication information. As a result, healthcare providers could access comprehensive and up-to-date patient information, enhancing clinical decision support and improving patient outcomes.

As showing in **Figure 2**, cloud computing exhibits an essential need to develop applications for high-performance data processing and management. There are numerous cloud service offerings for healthcare, covering a wide range of capabilities. This trend is highlighted through different applications and architecture based on cloud in healthcare.

3.2. Role of Artificial Intelligence (AI)

Artificial intelligence (AI) plays a crucial role in integrating mobile computing,

cloud computing, and FHIR. AI-powered analytics tools processed and analyzed the structured FHIR data to uncover valuable insights and patterns. It enabled the discovery of new correlations, risk factors, and treatments (Li et al., 2021). AI-enabled healthcare providers to access automated clinical decision support tools to improve their efficiency and enable them to make better decisions. The use of AI in clinical scenarios can help healthcare providers to create a more personalized care plan for each patient. There are still many challenges and controversies associated with the integration of mobile computing, cloud computing, and FHIR in healthcare systems across different regions and countries (Manickam et al., 2022). The application of AI algorithms and machine learning techniques enabled the identification of correlations, risk factors, and treatment options that might not be apparent to human eyes. This advanced analytics capability of AI enhanced the precision and accuracy of healthcare forecasts and improved the quality of patient care.

3.3. Clinical Decision Support and Predictive Modeling

The integration of mobile computing, cloud computing, FHIR, and AI resulted in the development of clinical decision support systems and predictive modeling tools. AI leveraged the FHIR data to provide evidence-based recommendations for healthcare providers (Gastounioti et al., 2022). These recommendations assisted in diagnostic accuracy, identification of potential treatment options, and personalized care planning based on a patient's unique medical history. Additionally, AI-driven predictive models utilized the FHIR data to identify at-risk patients, forecast disease progression, and estimate treatment outcomes. These models aided healthcare providers in proactively intervening and allocating resources more efficiently, ultimately leading to improved patient care and outcomes.

3.4. Discussion

The results of this study support the hypothesis that the integration of mobile computing, cloud computing, Fast Healthcare Interoperability Resources (FHIR), and artificial intelligence (AI) has the potential to revolutionize healthcare delivery (Ullah et al., 2020). Integrating mobile computing, cloud computing, FHIR, and AI provided numerous benefits for healthcare providers and improved patient care (Naseem et al., 2020). These applications enabled healthcare providers to access patient data in real-time while facilitating data exchange among diverse systems. Moreover, mobile devices and cloud platforms enabled the sharing of structured FHIR data and facilitated the accessibility of comprehensive patient information. This has led to better clinical decision support and improved quality of life for patients suffering from neurological disorders such as Parkinson's disease. Furthermore, in addition to improving patient care, these technologies provided healthcare providers with deep insights into the causes of disease progression.

AI Application	Description
Advanced Analytics	AI-powered tools process and analyze FHIR data for insights and patterns discovery.
Clinical Decision Support	AI leverages FHIR data to provide evidence-based recommendations and assist in informed decision-making.
Predictive Modeling	AI uses FHIR data to develop models for patient risk identification, disease progression forecasting, and treatment outcome estimation.

The findings of this study align with previous research that highlights the benefits of integrating mobile computing, cloud computing, and AI in healthcare. The inclusion of FHIR as a standardized framework further enhances the interoperability and accessibility of health information (Majeed & Hwang, 2022). Moreover, the results of this study are consistent with prior research demonstrating the positive impact of AI in predictive modeling, access to patient data, and clinical decision support.

3.5. Comparison with Previous Studies

The findings of this study are consistent with prior research that has highlighted the positive impact of mobile computing and cloud computing on healthcare outcomes. Integrating FHIR as a standardized framework for data exchange further strengthens the interoperability and accessibility of health information (Mbunge & Muchemwa, 2022). Moreover, the results of this study are consistent with previous research that has demonstrated the benefits of AI in predictive modeling, access to patient data, and clinical decision support.

3.6. Implications of the Findings

The implications of these findings are significant for healthcare providers, patients, and the industry as a whole. The integration of mobile computing, cloud computing, FHIR, and AI has the potential to improve patient care, enhance outcomes, and optimize healthcare processes (Chattu, 2021). By harnessing the power of advanced analytics and predictive modeling, healthcare providers can make more informed decisions, identify high-risk patients, and allocate resources effectively. This has the potential to reduce healthcare costs, minimize diagnostic errors, and optimize treatment strategies. However, it is important to acknowledge the limitations of this study. The interpretation of data is based on the extent to which researchers have filtered the raw data sources (Asan & Choudhury, 2021). Future research should encompass the analysis of multiple datasets from various healthcare systems and countries. This would provide a more comprehensive understanding of the impact of integrating mobile computing, cloud computing, FHIR, and AI in healthcare delivery.

3.7. Limitations and Future Research

The interpretation of data is based solely on the extent to which researchers have

filtered the raw data sources. Future research should include analyzing multiple datasets representing other healthcare systems and countries. This would allow for a more comprehensive understanding of the impact of mobile computing, cloud computing, FHIR, and AI in healthcare delivery.

4. Conclusion

In conclusion, the integration of mobile computing, cloud computing, Fast Healthcare Interoperability Resources (FHIR), and artificial intelligence (AI) holds immense potential to revolutionize healthcare delivery. The application of AI in healthcare settings can help healthcare providers to identify patient-specific risks and develop better care plans. The utilization of AI-enabled clinical decision support systems and predictive modeling tools can benefit patients by facilitating better diagnostic accuracy, improved patient outcomes, and reduced healthcare costs. The findings of this study demonstrate the benefits of these technologies in improving access to patient data, enhancing clinical decision support, and enabling advanced analytics and predictive modeling. It is important to address the challenges and considerations associated with the integration of these technologies. Data quality, security, privacy, interoperability, and ethical considerations must be carefully addressed to ensure the reliable and responsible use of these technologies in healthcare settings. Future research should focus on developing guidelines and best practices for the implementation and utilization of mobile computing, cloud computing, FHIR, and AI in healthcare, as well as evaluating their long-term impact on patient outcomes.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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