

Transforming Healthcare Through Cloud Computing

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Abstract

The dynamic evolution and progression of cloud computing technology have ushered in a paradigm shift within the healthcare sector, ushering in a multitude of advantages and reshaping the landscape of healthcare service delivery. Cloud computing stands out as a pivotal facilitator for healthcare entities, furnishing them with the flexibility, scalability, and cost-effectiveness required to navigate the ever-expanding demands of contemporary healthcare. Cloud computing in healthcare reduces the necessity for substantial investments in IT infrastructure, enabling institutions to concentrate more on patient care. It offers access to computing resources on a pay-as-you-go basis, allowing for scalability and adaptability to meet patient needs. It ensures high levels of data security and privacy in healthcare by implementing robust security measures and encryption protocols. Cloud-based systems also feature data redundancy and disaster recovery functionalities, ensuring the availability and integrity of patient data even during system failures or natural disasters.

Keywords: Cloud computing, healthcare sector, patient data, data storage, Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS)

INTRODUCTION

Cloud computing has emerged as a transformative technology with the potential to revolutionize the healthcare industry. By providing on-demand access to a vast pool of computing resources, cloud computing enables healthcare organizations to improve patient care, enhance operational efficiency, and reduce costs. This paper delves into the transformative impact of cloud computing on healthcare, exploring its key benefits, applications, and challenges [1]. Cloud computing offers numerous benefits to the healthcare industry, including improved patient care, enhanced operational efficiency, reduced costs, increased scalability, and enhanced data security.

LITERATURE REVIEW

Transformative Impact

Cloud computing is fundamentally altering the landscape of healthcare by offering scalable resources and economical solutions to meet variable demands efficiently. This technological shift is enabling healthcare providers to handle increasing workloads with greater flexibility [2].

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Received Date: March 19, 2024
Accepted Date: May 20, 2024
Published Date: May 20, 2024

Citation: Harsh Ghoghari, Arpita Mishra. Transforming Healthcare Through Cloud Computing. International Journal of Software Computing and Testing. 2024; 10(1): 34–43p.

Key Benefits

The integration of cloud computing in healthcare yields several advantages. It significantly enhances patient care by ensuring timely access to information and seamless communication among healthcare professionals. Operational efficiency is boosted through streamlined processes and improved data management systems. Additionally, cloud solutions offer robust data security measures, cost reductions, and unparalleled scalability, making them attractive to healthcare organizations.

Challenges

Despite the promising potential of cloud computing in healthcare, its adoption is hindered by several challenges. Foremost among these are concerns regarding data privacy and security. The sensitive nature of healthcare information necessitates stringent safeguards to protect against breaches and unauthorized access, posing a significant barrier to widespread implementation.

Current Research

Ongoing studies in the field of cloud computing in healthcare cover a broad spectrum of applications. Research topics include the enhancement of telemedicine services, advancements in medical imaging technologies, improvements in public health tracking and management, optimization of hospital management systems, innovative therapeutic interventions, and the effective use of secondary data for research and policymaking. These studies highlight the importance of successful cloud computing implementations to realize the full potential of this technology in healthcare.

METHODOLOGY

The research methodology for investigating the impact, benefits, challenges, and current research on cloud computing in healthcare will employ a mixed-methods approach. This comprehensive strategy integrates both qualitative and quantitative research techniques to provide a refined understanding of the topic [3].

- *Sources:* Using industry reports, and authoritative websites of respective healthcare to gather sufficient information.
- *Process:* Conducting a systematic search and selection of relevant information to perform an analysis to identify the advantages of cloud services in the healthcare sector.
- *Case studies:* Identifying diverse healthcare organizations (e.g., hospitals, clinics, telemedicine providers) that have adopted cloud computing.
- *Data collection:* Conduct a structured search on respective key stakeholders (e.g., IT Infrastructures, healthcare providers, patients) and review open-source information available on their authoritative websites.

CLOUD COMPUTING

Cloud computing emerges as a technological marvel, offering a diverse array of computing services spanning servers, storage, databases, networking, software, analytics, and intelligence, all accessible through the expansive landscape of the Internet, commonly referred to as the “cloud.” This paradigm shift mirrors the concept of leasing computational power rather than committing to full-scale purchases [4]. The conventional approach of acquiring, owning, and maintaining physical data centers and servers gives way to the flexibility of obtaining technology services—such as computing prowess, storage, and databases—on a need-driven basis from renowned cloud providers like Amazon Web Services (AWS).

The National Institute of Standards and Technology, a branch of the U.S. Department of Commerce, meticulously delineates this technological masterpiece through five pivotal characteristics, three service models, and four deployment models. These characteristics unfold with distinct nuances [5]:

1. *On-demand self-service:* Users of cloud computing can seamlessly access computing capabilities on an individual basis, tailoring server periods and network storage according to spontaneous needs, all without direct human interaction with the service provider.
2. *Broad network access:* The accessibility of computing resources extends over networks and can be harnessed through diverse client platforms, including mobile devices, laptops, desktops, and more.
3. *Resource pooling:* Service providers use a multi-tenant model to serve multiple consumers, dynamically sharing computing resources. This approach allows for the flexible allocation and reassignment of both physical and virtual resources, adapting dynamically to consumer demand without revealing control or knowledge of the exact resource location.

4. *Rapid elasticity*: Cloud computing exhibits the ability to elastically provision and release resources, scaling swiftly both outward and inward in response to demand. This agility in scaling is automated in select cases, addressing consumer concerns about provisioning capabilities matching demand fluctuations.
5. *Measured service*: Clients exercise monitoring and control over the computing resources they utilize, facilitated through meters at varying abstraction levels depending on the service type. This implementation enables transparent reporting of resource usage through metering capabilities, fostering clarity and accountability between the cloud service provider and the customer.

Service Models

Cloud Computing utilizes remote Internet servers for data storage, management, and processing, instead of local servers or personal computers. Cloud providers offer these services and charge based on usage. The structural basis of cloud computing is rooted in grids and clusters [6].

Cloud computing service models come in three main types: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) are organized in a layered architecture, with each layer building on one below it. For instance, SaaS can leverage IaaS, highlighting the interconnected nature of these services. Grasping these distinctions aids in achieving specific objectives and showcases the versatility of cloud computing [7].

Software as a Service (SaaS): Software-as-a-Service (SaaS) provides applications over the Internet, relieving users from the burden of managing software and hardware. This model lowers costs by removing the need for local installations and maintenance. Users can access software on a pay-as-you-go basis directly through a web browser, eliminating the need for downloads or installations. Also known as Web-based, on-demand, or hosted software, SaaS improves efficiency and accessibility [8].

Platform as a Service (PaaS): Platform as a Service (PaaS) provides developers with a cloud-based platform for creating and deploying applications, accessible via web browsers. By hosting the necessary hardware and software on their infrastructure, PaaS providers eliminate the need for in-house resources, allowing developers to focus solely on their applications without managing the underlying systems. Though users don't control the cloud infrastructure, they do manage their applications and some configuration settings. This is akin to choosing between building a venue or renting one for an event—both achieve the same goal [9].

Infrastructure as a Service (IaaS): Infrastructure as a Service (IaaS), also referred to as Hardware as a Service (HaaS), involves outsourcing critical computing infrastructure such as networking equipment, databases, and servers. Businesses pay based on usage, whether hourly, weekly, or monthly. IaaS provides the foundational components—operating systems, security, networking, and servers—needed for developing and deploying applications, allowing users to focus on innovation without managing the underlying infrastructure as shown in Figure 1.

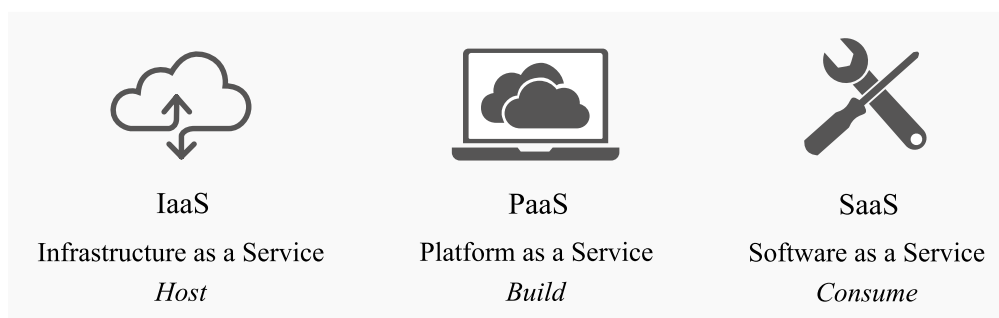


Figure 1. Three major cloud service models.

Deployment Models

Cloud Deployment Models offer adaptable virtual computing environments tailored to data storage and infrastructure needs. They define the configuration, ownership, scale, access, and purpose of the cloud infrastructure, specifying what can be modified and whether services are provided or require a DIY approach. These models shape the interaction between infrastructure and users, encompassing various categories with unique characteristics [10].

Public Cloud

The public cloud emerges as an inclusive realm, granting universal access to systems and services. While its openness fosters accessibility, it may pose security challenges due to its unrestricted nature. This deployment model extends cloud infrastructure services over the internet, catering to both the general public and major industry groups. Owned by the entity delivering the services, this form of cloud hosting exemplifies accessibility, with service providers offering a spectrum of services to a diverse clientele. Notable examples include Google App Engine, showcasing storage, backup, and retrieval services on a complimentary, subscription, or per-user basis.

Private Cloud

In stark contrast, the private cloud deployment model offers a tailored, one-on-one environment for a singular user or customer. Within this exclusive setup, there's no need to share hardware resources, offering enhanced control and security. Often called the 'internal cloud,' it allows access to systems and services within a defined boundary or organization. The cloud platform operates within a secure environment fortified by robust firewalls and overseen by the organization's IT department, bestowing unparalleled control over cloud resources.

Hybrid Cloud

Serving as a harmonious intersection of the public and private spheres, hybrid cloud computing introduces a layer of proprietary software to amalgamate the best of both worlds. This hybrid solution facilitates secure application hosting while capitalizing on the cost efficiencies of the public cloud. Organizations leverage a combination of two or more cloud deployment methods, seamlessly moving data and applications between distinct clouds based on their specific requirements.

Community Cloud

Designed to serve a collective of organizations, the community cloud fosters accessibility to systems and services tailored to the shared needs of a specific community, industry, or business. This distributed system integrates services from different clouds, potentially shared among organizations with common concerns or tasks. Managed either by a third party or a collaborative effort from multiple organizations within the community, the community cloud offers a targeted solution addressing the unique requirements of its constituents.

CLOUD COMPUTING IN HEALTHCARE SECTOR

Cloud computing in healthcare revolutionizes medical record-sharing, streamlines backend operations, and supports the development of telehealth apps. Its adoption enhances industry efficiency and reduces costs significantly [11]. The exponential expansion of cloud technology within the healthcare sector is undeniable and forecasted to exceed \$89 billion in global expenditure by 2027. Notably, Infrastructure as a Service (IaaS) emerges as a preferred model for transitioning healthcare infrastructures to the cloud, poised to achieve a significant compound annual growth rate (CAGR) of 32 percent by 2027. This underscores the transformative potential and widespread adoption of cloud computing in modern healthcare.

The healthcare industry faces high operational costs and the challenge of creating a self-sustaining ecosystem, primarily due to the need to handle large amounts of sensitive information. Technology,

particularly cloud computing, offers innovative solutions to these challenges. Cloud computing has emerged as a transformative catalyst within the healthcare sector, offering capabilities such as collaboration, scalability, efficiency, and robust security measures. Its on-demand capabilities enable quick deployment and management of network information, driving essential changes in how healthcare data is created, stored, and shared.

Cloud-based Healthcare Systems

Cloud-based healthcare systems enable secure, scalable, and efficient management of medical data, enhancing patient care through accessible and collaborative platforms.

Cloud Computing for Clinical Development and Research

Renowned for its wide array of software applications, Microsoft has made significant strides in serving the healthcare sector. Azure, its cloud-based platform, leverages AI and IoT technologies to monitor patient insights and analytics seamlessly within the cloud. Complementing this, Microsoft's HoloLens 2 can project holographic images containing cloud-stored information, empowering healthcare providers with accessible patient data and collaborative resources for diagnoses, operations, and treatment.

Pfizer, a prominent pharmaceutical and biotechnology company, has been at the forefront of leveraging cloud services since 2016. Its partnership with BioNTech resulted in the creation of a revolutionary COVID-19 vaccine, propelling Pfizer into international prominence. Expanding its innovative efforts, Pfizer has partnered with Amazon Web Services (AWS) to pioneer cloud-based solutions aimed at enhancing the speed and efficiency of various healthcare processes. These initiatives focus on accelerating clinical trial testing, as well as optimizing the development, manufacturing, and distribution of pharmaceutical products. Through its strategic utilization of cloud technology, Pfizer continues to revolutionize the healthcare industry, driving advancements in medical research and patient care on a global scale [12].

Cloud Computing for Electronic Health Record Management

TigerConnect stands out as a leading cloud-based software company specializing in healthcare solutions. The messaging platform, compliant with HIPAA regulations, empowers healthcare professionals by providing a secure means to exchange messages, records, patient data, and documents. Unlike traditional communication methods, TigerConnect facilitates seamless collaboration on documents and treatment plans, enhancing efficiency and patient care. One distinctive application of the software is its innovative approach to physician on-call scheduling. Utilizing a sophisticated scheduling system, TigerConnect can generate a year's worth of schedules nearly instantaneously, streamlining workflow and ensuring uninterrupted access to medical expertise. This unique capability underscores TigerConnect's commitment to leveraging cloud technology to revolutionize healthcare communication and operational efficiency.

Consensus Cloud Solution's range of products endeavors to address healthcare challenges and boost productivity by leveraging cloud technology to ensure accessibility of patient data and other essential information, previously in paper form, for healthcare providers. Their suite of solutions comprises HIPAA-compliant tools such as jSign for electronic signatures and eFax Corporate for cloud-based faxing.

Cloud Computing for Patient Experience

EPAM (Effective Programming for America) distinguishes itself as a premier provider of IT consultancy services tailored specifically to the healthcare and life sciences sector. With a focus on integrating technology seamlessly into client processes, EPAM employs a holistic approach that combines physical, digital, and data platform products. This unique strategy enables EPAM to develop

innovative tech strategies centered around enhancing the patient experience. Leveraging its expertise in modernization and cloud migration, EPAM delivers tailored solutions that align with client objectives and industry best practices. Notably, EPAM's portfolio showcases its collaboration on a cloud-based digital experience platform enriched with AI-powered features. These features encompass data analytics, physician engagement tools, and streamlined business operations, further solidifying EPAM's commitment to driving digital transformation and innovation in healthcare.

Why are Health Care Organizations Moving to Cloud

The healthcare sector is experiencing a revolutionary shift propelled by cloud computing, leveraging its unmatched on-demand accessibility, extensive data availability, and internet-driven services. This innovative technology has garnered increasing adoption among tech-savvy medical professionals, who recognize its manifold benefits in effectively addressing both patient and business needs as shown in Figure 2. Among the myriad advantages of cloud computing in healthcare, several stand out as particularly impactful:

- *Lowers healthcare cost:* The primary benefits of cloud computing in healthcare are real-time access to data storage and computing power, and a pay-as-you-go pricing model with no upfront costs. It enables cost-effective scaling to accommodate data from various sources like EMRs, healthcare apps, and wearables.
- *Easy interoperability:* Interoperability ensures seamless data integration across the healthcare system, making patient data easily accessible for distribution and insights. Cloud computing facilitates access to diverse patient data, sharing with stakeholders, and timely protocol delivery for medical professionals.
- *Ownership of patients' data:* Cloud computing in healthcare democratizes data, empowering patients to control their health and participate in decision-making. It enhances patient engagement and education while enabling easy archiving and retrieval of medical data. Improved system uptime reduces data redundancy and facilitates easier data recovery.
- *Improves collaboration:* Healthcare cloud adoption enhances collaboration among stakeholders, providers, and patients by storing Electronic Health Records (EHRs) in the cloud. This eliminates the need for patients to carry physical records to each visit and enables doctors to access, share, and review information in real time. Enhanced availability of patient data results in treatment that is more tailored and efficient, leading to improved outcomes.
- *Enhances patients' experience:* By offering real-time access to medical data, test results, and physicians' notes, cloud computing in healthcare promotes patient engagement. Additionally, it aids in reducing overprescription and unnecessary testing by granting patients access to their medical records.

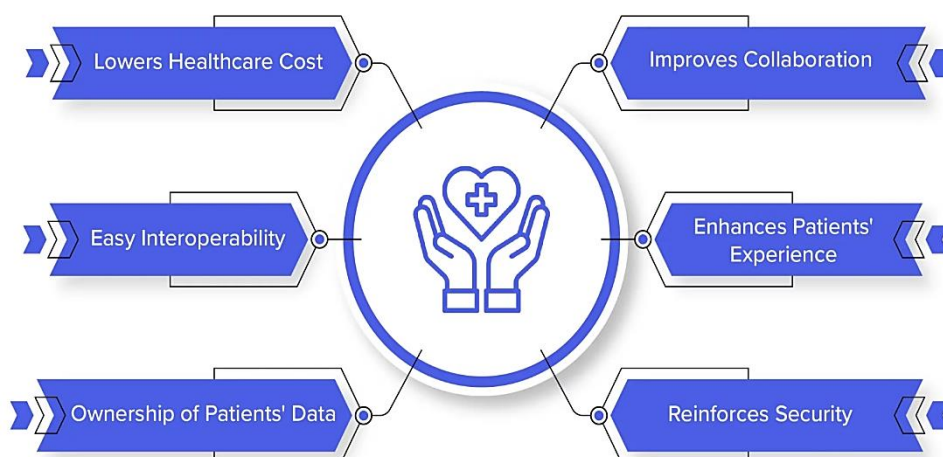


Figure 2. Benefits of cloud computing in healthcare.

- *Reinforces security:* Cloud computing in healthcare helps mitigate the risk of data breaches and cyber-attacks by providing failsafe security measures. These applications can proactively alert users about suspicious attempts, enhancing overall data protection.

In the ever-evolving landscape of healthcare technology, the cloud stands as a pivotal ally, addressing the unique challenges faced by healthcare organizations and ushering in a new era of efficiency, collaboration, and cost-effectiveness in the delivery of healthcare services.

Indian Health Sector Which Uses Cloud Services

The Indian health sector leveraging cloud services for enhanced efficiency, accessibility, and data management.

Apollo Hospitals partners with Google Cloud

Apollo Hospitals has extended its collaboration with Google Cloud to empower every Indian with access to healthcare through Apollo's digital platform, Apollo 24|7.

The development of an AI-powered clinical decision support system: Apollo 24|7 has partnered with Google Cloud to lead the way in innovative healthcare solutions by introducing a state-of-the-art Clinical Intelligence Engine (CIE), leveraging the capabilities of Google Cloud's Vertex AI and generative AI (gen AI) models. This groundbreaking technology empowers doctors to make informed decisions and identify the optimal course of action for patients during consultations. The CIE service stands out for its utilization of data sourced from Apollo Hospitals and sophisticated large language models (LLMs) from Google Cloud, culminating in a proprietary solution that prioritizes patient data security by keeping it securely within the hospitals' systems. This innovative partnership underscores Apollo 24|7's commitment to leveraging advanced technology to revolutionize healthcare delivery and enhance patient care outcomes.

The AskApollo patient-facing service: Apollo's AskApollo platform stands as a pioneering care navigation service utilizing the Clinical Intelligence Engine (CIE), an innovative solution crafted from decades of Apollo's clinical excellence and backed by millions of real-world clinical data points. This innovative platform is powered by Google Cloud's advanced AI and machine learning technologies, distinguishing it as a first-of-its-kind service in the healthcare industry. Moreover, Apollo Hospitals is at the forefront of exploring the capabilities of Med-PaLM 2, an advanced large language model (LLM) developed by Google specifically for medical applications. Trained in vast medical knowledge, Med-PaLM 2 can effectively answer medical queries and generate clinical text summaries, further enhancing Apollo's commitment to providing cutting-edge healthcare solutions that prioritize patient well-being and satisfaction.

Providing a highly scalable, modernized cloud platform for Apollo 24|7: In partnership with Google Cloud collaborator Search, Apollo 24|7, India's premier and rapidly expanding health platform, successfully implemented 78 microservices and over 40 databases on Google Cloud without any interruptions. Additionally, Apollo 24|7's data lake, hosted on Google BigQuery, consolidates fragmented data sources onto one unified platform, fostering improved decision-making processes and clinical outcomes.

Delivering authentic healthcare information on Search: Google's collaboration with Apollo Hospitals represents a unique synergy between advanced AI capabilities and decades of healthcare expertise. By leveraging Google's deep AI capabilities and Apollo Hospital's extensive 40-year experience in healthcare, this partnership has the potential to revolutionize the accessibility, accuracy, and affordability of diagnosis. Through sourcing authoritative and helpful health information for features on Google Search, the collaboration aims to empower individuals with reliable and relevant medical information. This unique blend of cutting-edge technology and healthcare knowledge positions Google and Apollo Hospitals at the forefront of driving positive changes in the healthcare landscape, ultimately benefiting patients worldwide.

Max Healthcare and Dell Services: The Cloud Advantage

Dell Services has transformed Max Healthcare's IT infrastructure by migrating all eight facilities to a private MPLS (Multi-Protocol Label Switching) cloud, which is managed remotely from the Dell Services Data Centre in Noida. This innovative approach not only enhances the availability of healthcare information systems and analytical tools but also paves the way for the implementation of Electronic Health Records (EHR).

The robust cloud infrastructure provided by Dell Services enables Max Healthcare to seamlessly integrate EHR and Computerized Physician Order Entry systems, leading to enhanced stability and availability of IT resources across its hospitals. This transformation has resulted in improved access to Healthcare Information Systems (HIS) and data analytics tools, thereby empowering healthcare professionals to make informed decisions and deliver superior patient care.

The private MPLS cloud architecture offers Max Healthcare the flexibility to effortlessly deploy its processes and tools at new facilities, simplifying the onboarding process for additional sites. By granting access to Max's HIS through the cloud, the private MPLS cloud facilitates rapid scalability and expansion of Max Healthcare's operations across India, ensuring continuity of care and operational efficiency across its growing network of facilities. This unique collaboration between Dell Services and Max Healthcare exemplifies a forward-thinking approach to healthcare IT infrastructure, setting new benchmarks for reliability, scalability, and patient-centric care delivery in the industry.

Manipal Hospitals Partners with Google Cloud

Manipal Hospitals is embarking on an innovative journey by harnessing Google Cloud's cutting-edge technology to revolutionize healthcare delivery across its chain of hospitals in the country. This strategic partnership with Google Cloud encompasses multiple transformative initiatives aimed at enhancing patient care and accessibility.

Firstly, Manipal Hospitals is set to leverage Google Cloud's Amwell telehealth platform to enable virtual visits, marking a significant step towards expanding access to remote healthcare services. This collaboration underscores Google Cloud's commitment to advancing virtual care delivery, with features such as automated waiting room and checkout processes, language translation services, and intelligent case triaging, all aimed at optimizing the telehealth experience for patients and healthcare providers alike.

In addition to virtual care, Manipal Hospitals' partnership with Google Cloud extends to the creation of a state-of-the-art e-pharmacy platform and the development of a remote patient monitoring system. These initiatives aim to streamline medication ordering processes and enhance patient monitoring capabilities, fostering greater convenience and efficiency in healthcare delivery.

Moreover, Manipal Hospitals is poised to leverage Google Cloud's conversational AI tools to enhance patient interactions, including appointment booking and doctor searches, thereby enriching the overall patient experience and accessibility to care.

Furthermore, Manipal Hospitals has recently forged strategic partnerships with leading healthcare technology companies, such as Isansys Lifecare and ConnectedLife, to bolster its remote care capabilities. By deploying cutting-edge remote patient monitoring systems and virtual platforms, Manipal Hospitals demonstrates its commitment to leveraging innovative technologies to improve patient outcomes and expand access to high-quality healthcare services.

Sahyadri Hospitals Leverages AWS Cloud Services

Sahyadri Hospitals, Maharashtra's largest hospital chain boasting 925 beds, has embarked on a transformative journey by embracing AWS cloud services to optimize operations and elevate patient

care standards. Through this strategic partnership, Sahyadri Hospitals has successfully consolidated data and achieved centralized views, leading to enhanced efficiency and substantial cost reductions in infrastructure management. Moreover, seamless access to patient records across all hospitals has significantly bolstered patient satisfaction, underscoring Sahyadri Hospitals' commitment to delivering superior healthcare experiences.

By leveraging AWS cloud's scalable model, Sahyadri Hospitals effectively manages escalating data capacities while mitigating infrastructure costs and minimizing downtime. This scalable approach not only ensures seamless expansion but also underscores Sahyadri Hospitals' proactive stance in addressing the evolving needs of modern healthcare delivery.

The unique collaboration between Sahyadri Hospitals and AWS serves as a beacon of innovation in the healthcare landscape, epitomizing the transformative potential of cloud adoption. By overcoming common data management challenges and prioritizing patient-centric care, Sahyadri Hospitals sets a precedent for healthcare organizations striving to leverage technology to enhance patient outcomes and operational efficiency.

CONCLUSION

Integrating cloud services into healthcare significantly boosts data accessibility, collaboration, and scalability, while maintaining regulatory compliance. Cloud solutions enhance advanced technologies such as AI and telemedicine, leading to better diagnoses and wider access to care. Although data security and privacy concerns persist, robust cybersecurity measures and thorough staff training can address these issues. Ultimately, cloud services are crucial in revolutionizing healthcare, improving operational efficiency, patient care, and fostering innovation in medical research and treatment methodologies.

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