

Hybrid Cloud Adoption: A Paradigm Shift in Modern Information Technology Management

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Abstract: *The rapid evolution of information technology has led to the emergence of hybrid cloud infrastructure as a critical component in modern enterprise IT strategies. This article examines the growing significance of hybrid cloud solutions, which integrate on-premises, private cloud, and public cloud services, in reshaping the IT and tech landscape. We explore how this model offers unprecedented flexibility, scalability, and cost optimization opportunities for businesses across various sectors. The article delves into industry-specific applications, focusing on healthcare and financial services, where hybrid cloud solutions are driving transformative changes in data management, analytics, and operational efficiency. Furthermore, we investigate the synergistic relationship between hybrid cloud infrastructure and artificial intelligence applications, highlighting how this combination is accelerating innovation and enabling advanced capabilities such as predictive maintenance and personalized customer experiences. Through a comprehensive analysis of its benefits, challenges, and future prospects, this article argues that hybrid cloud infrastructure is not merely a technological trend, but a fundamental shift in how organizations approach their IT resources, security, and digital transformation strategies. As such, it represents a pivotal development in the ongoing evolution of cloud computing and its impact on business operations and competitiveness in the digital age.*

Keywords: hybrid cloud infrastructure, enterprise it transformation, cloud computing optimization, industry-specific cloud solutions, AI-cloud integration.

INTRODUCTION

The landscape of enterprise IT is undergoing a profound transformation, driven by the growing adoption of hybrid cloud infrastructure. This innovative approach, which seamlessly integrates on-premises, private cloud, and public cloud services, is rapidly becoming a cornerstone of modern IT strategies [1]. As organizations grapple with the dual challenges of maintaining operational efficiency and fostering

innovation, hybrid cloud solutions offer a compelling framework that balances flexibility, scalability, and cost-effectiveness. The significance of this shift extends beyond mere technological adoption; it represents a fundamental reimagining of how businesses leverage IT resources to drive competitive advantage and digital transformation [2]. This article explores the multifaceted impact of hybrid cloud infrastructure across various industries, with a particular focus on its synergistic relationship with emerging technologies such as artificial intelligence. By examining both the benefits and challenges of hybrid cloud adoption, we aim to provide a comprehensive understanding of its growing importance in shaping the future of IT and business operations.

The integration of Artificial Intelligence (AI) with hybrid cloud infrastructure is ushering in a new era of intelligent, adaptive, and efficient cloud computing. AI technologies are not only benefiting from the scalability and flexibility of hybrid clouds but are also enhancing the management, security, and optimization of these complex environments. This synergy between AI and hybrid cloud is driving innovation across industries, from healthcare to finance, manufacturing to retail, revolutionizing how organizations leverage their IT resources and process data.

Understanding Hybrid Cloud Infrastructure

A. Definition and components

Hybrid cloud infrastructure represents a sophisticated IT paradigm that combines and orchestrates multiple computing environments to create a unified, flexible, and scalable system. At its core, a hybrid cloud integrates on-premises infrastructure, private cloud services, and public cloud platforms into a cohesive ecosystem [3]. This model allows organizations to leverage the strengths of each environment while mitigating their individual limitations.

The key components of a hybrid cloud infrastructure typically include:

1. On-premises infrastructure: Traditional data centers or locally managed servers that house critical applications and sensitive data.
2. Private cloud: A cloud environment dedicated to a single organization, either managed internally or by a third-party provider, offering enhanced control and security.
3. Public cloud: Shared computing resources provided by third-party vendors like Amazon Web Services (AWS), Microsoft Azure, or Google Cloud Platform (GCP).
4. Cloud management platform: Software that enables seamless integration, orchestration, and management across different cloud environments.
5. Network connectivity: Robust and secure network infrastructure that facilitates communication between various cloud components.
- 6.

Integration of on-premises, private cloud, and public cloud services

The integration of these diverse environments is a complex process that requires careful planning and execution. Organizations typically employ a combination of strategies to achieve seamless integration:

1. Application and data portability: Utilizing containerization technologies like Docker and orchestration tools like Kubernetes to ensure applications can run consistently across different environments.
2. Unified management interfaces: Implementing cloud management platforms that provide a single pane of glass for monitoring, managing, and optimizing resources across all environments.
3. Network connectivity and security: Establishing secure, high-performance connections between on-premises infrastructure and cloud services, often using technologies like VPNs or dedicated connections (e.g., AWS Direct Connect or Azure ExpressRoute).
4. Identity and access management: Implementing federated identity solutions to ensure consistent authentication and authorization across all environments.
5. Data synchronization and replication: Utilizing tools and services that maintain data consistency across different environments, enabling scenarios like disaster recovery and load balancing.

This integration allows organizations to create a fluid IT environment where workloads can be dynamically allocated to the most appropriate platform based on factors such as performance requirements, cost considerations, and compliance needs [4]. For instance, an e-commerce company might process sensitive customer data on its private cloud while leveraging the scalability of a public cloud to handle traffic spikes during peak shopping seasons. By successfully integrating these diverse components, organizations can harness the full potential of hybrid cloud infrastructure, gaining the agility to respond to changing business needs while maintaining control over critical assets and data.

Artificial Intelligence is playing an increasingly crucial role in facilitating this integration. AI-powered tools are automating the complex processes of workload distribution, data synchronization, and security management across diverse cloud environments. These intelligent systems can analyze patterns in data flow and resource utilization, making real-time decisions to optimize the integration of on-premises, private cloud, and public cloud services.

Table 1: Comparison of Cloud Deployment Models [1, 2]

Characteristic	Public Cloud	Private Cloud	Hybrid Cloud
Infrastructure ownership	Cloud provider	Organization	Mix of both
Location	Off-premises	On-premises or hosted	Distributed
Cost model	Pay-as-you-go	Capital expenditure	Mix of both
Scalability	High	Limited	High
Security control	Limited	High	Customizable
Performance	Variable	Consistent	Optimized
Use cases	Web applications, dev/test	Sensitive data processing	Most enterprise applications

Drivers of Hybrid Cloud Adoption

A. Flexibility and scalability requirements

The dynamic nature of modern business environments necessitates IT infrastructures that can rapidly adapt to changing demands. Hybrid cloud adoption is primarily driven by the need for flexibility and scalability that traditional on-premises solutions often struggle to provide [5]. Organizations require the ability to quickly scale resources up or down based on fluctuating workloads, seasonal demands, or unexpected market shifts.

Hybrid cloud infrastructure offers this flexibility by allowing businesses to:

1. Burst into public cloud resources during peak demand periods.
2. Maintain sensitive workloads on-premises or in private clouds while leveraging public clouds for less critical tasks.
3. Seamlessly move applications and data between different environments as needs evolve.
4. Rapidly deploy new services or applications without significant upfront infrastructure investments.

This flexibility enables organizations to respond more effectively to market opportunities, accelerate innovation, and improve overall business agility.

Cost optimization strategies

1. Balancing public and private cloud resources

Hybrid cloud adoption allows organizations to optimize costs by strategically allocating workloads between public and private cloud resources. This balance is achieved by:

- Utilizing cost-effective public cloud services for variable or unpredictable workloads.
- Leveraging private cloud or on-premises infrastructure for consistent, high-performance workloads or those with specific compliance requirements.
- Implementing cloud bursting techniques to handle peak loads without overprovisioning in-house resources.

Reduction in capital expenditure

One of the significant drivers of hybrid cloud adoption is the potential for substantial reductions in capital expenditure (CapEx). By leveraging public cloud services, organizations can:

- Minimize upfront investments in hardware and data center infrastructure.
- Reduce costs associated with maintaining and upgrading physical infrastructure.
- Shift IT spending from CapEx to operational expenditure (OpEx), improving financial flexibility.

Pay-as-you-go model advantages

The pay-as-you-go model offered by public cloud providers is a key component of hybrid cloud cost optimization [6]. This model, which is a fundamental characteristic of cloud computing, provides several advantages:

- Improved cost alignment: Organizations only pay for the resources they actually use, aligning costs more closely with business value.
- Enhanced budget predictability: Usage-based billing allows for more accurate forecasting of IT expenses.
- Reduced risk of over-provisioning: Companies can avoid the costs associated with maintaining underutilized infrastructure.
- Flexibility to scale: Organizations can easily scale resources up or down based on actual demand, without long-term commitments.

By adopting a hybrid cloud approach, organizations can leverage these cost optimization strategies to achieve a more efficient and cost-effective IT infrastructure. This allows businesses to redirect financial resources from maintaining legacy systems to driving innovation and growth initiatives.

AI-Driven Enhancements

The integration of AI technologies is becoming a significant driver for hybrid cloud adoption. AI offers several benefits in a hybrid cloud environment:

1. Intelligent resource allocation and cost optimization
2. Enhanced security through real-time threat detection and response
3. Improved operational efficiency with AI-powered management tools

4. Advanced data analytics capabilities leveraging distributed cloud resources These AI-driven enhancements are compelling organizations to adopt hybrid cloud solutions to stay competitive and innovative in their respective industries.

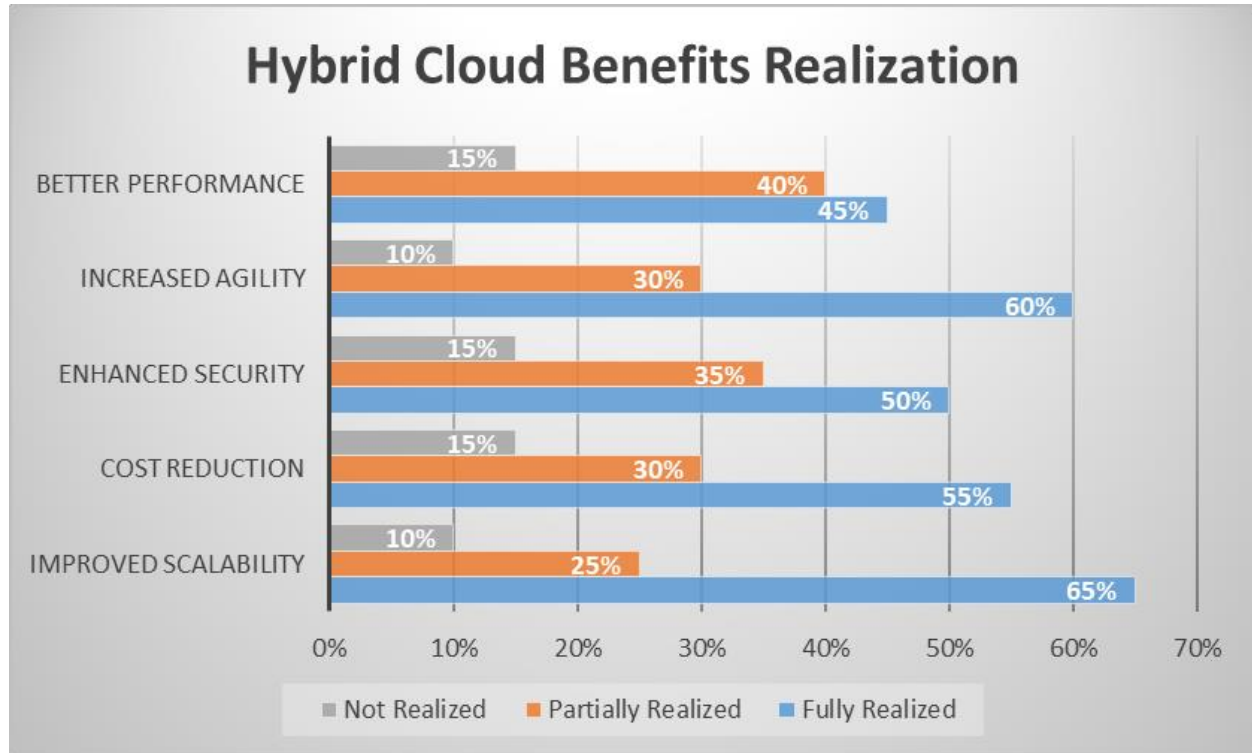


Fig. 1: Hybrid Cloud Benefits Realization (% of Organizations Reporting) [4, 6]

Industry-Specific Applications and Benefits

A. Healthcare sector

The healthcare industry has been experiencing a digital transformation, with hybrid cloud solutions playing a pivotal role in enhancing patient care, improving operational efficiency, and ensuring data security [7].

1. Secure data management

Hybrid cloud infrastructure enables healthcare organizations to:

- Store sensitive patient data on-premises or in private clouds, ensuring compliance with regulations like HIPAA.
- Utilize public cloud resources for non-sensitive data and applications, optimizing costs.
- Implement robust encryption and access control measures across all environments.
- Facilitate secure data sharing between healthcare providers, improving coordinated care.

2. Advanced analytics for improved patient care

By leveraging the power of hybrid cloud, healthcare providers can:

- Analyze large datasets combining clinical, operational, and external data sources.
- Implement machine learning models for predictive diagnostics and personalized treatment plans.
- Enable real-time analytics for monitoring patient conditions and early intervention.
- Support population health management initiatives through comprehensive data analysis.

3. Operational efficiency enhancements

Hybrid cloud adoption in healthcare leads to:

- Streamlined electronic health record (EHR) systems with improved accessibility and reduced downtime.
- Enhanced telemedicine capabilities through scalable cloud resources.
- Optimized resource allocation in hospitals and clinics based on predictive analytics.
- Improved supply chain management and inventory control for medical supplies.

5. AI-driven data analysis: Hybrid cloud environments enable the processing of vast amounts of healthcare data using AI algorithms, facilitating personalized medicine approaches and population health management.

B. Financial services

The financial services sector has embraced hybrid cloud solutions to address its unique challenges related to security, compliance, and high-performance computing needs [8].

1. Robust disaster recovery capabilities

Hybrid cloud infrastructure enables financial institutions to:

- Implement geographically dispersed backup and recovery systems.
- Ensure business continuity with rapid failover between on-premises and cloud environments.
- Conduct regular disaster recovery testing without impacting production systems.
- Maintain data sovereignty by keeping critical data within specific jurisdictions.

2. Real-time processing advancements

The adoption of hybrid cloud in financial services facilitates:

- High-frequency trading systems with low-latency connections to financial markets.
- Real-time fraud detection and prevention using advanced analytics and machine learning.
- Instant payment processing and settlement across global financial networks.
- Dynamic risk assessment and portfolio management.

3. Compliance and transaction security improvements

Hybrid cloud solutions help financial institutions:

- Maintain compliance with regulations such as GDPR, PCI DSS, and MiFID II by keeping sensitive data in controlled environments.

- Implement advanced encryption and tokenization techniques across hybrid environments.
 - Enhance identity and access management with multi-factor authentication and role-based access control.
 - Conduct comprehensive auditing and monitoring of all transactions and data access.
5. AI-powered real-time fraud detection: Leveraging the computational power of hybrid clouds, AI systems can analyze transactions across multiple platforms simultaneously, enhancing security and reducing financial risks.
 - 6.

By leveraging hybrid cloud infrastructure, both healthcare and financial services sectors can achieve a balance between innovation, security, and regulatory compliance. This approach allows these industries to modernize their IT systems, improve service delivery, and enhance overall operational efficiency while maintaining the highest standards of data protection and regulatory adherence.

Table 2: Benefits of Hybrid Cloud Adoption Across Industries [7, 8, 10]

Industry	Key Benefits	Example Application
Healthcare	Secure patient data management, Advanced analytics for diagnostics, Telemedicine support	Predictive analytics for patient outcomes
Financial Services	Real-time transaction processing, Enhanced security and compliance, Disaster recovery	High-frequency trading systems
Manufacturing	IoT integration, Supply chain optimization, Predictive maintenance	Real-time production line monitoring
Retail	Personalized customer experiences, Inventory management, Omnichannel support	AI-driven recommendation engines
Media & Entertainment	Content delivery optimization, Render farm scalability, User engagement analytics	Streaming service with dynamic scaling

C. Manufacturing

1. IoT integration and edge computing: Hybrid cloud architectures support AI-powered IoT devices and edge computing for real-time data processing and decision-making in smart factories.

2. Predictive maintenance: AI algorithms analyzing data from sensors across hybrid cloud environments can predict equipment failures, optimizing maintenance schedules and reducing downtime.

D. Hybrid MultiCloud Solutions

Leading companies like Nutanix and VMware are at the forefront of hybrid multicloud solutions, offering platforms that seamlessly integrate on-premises, private cloud, and multiple public cloud environments [13].

Nutanix provides hybrid multicloud infrastructure through its Nutanix Cloud Clusters (NC2), which allows organizations to extend their on-premises infrastructure to public clouds. VMware offers vSphere, a platform that ensures consistent infrastructure and operations across hybrid and multi-cloud environments. These solutions provide several key benefits:

1. Flexibility and choice: Organizations can choose the best environment for each workload, avoiding vendor lock-in.
2. Consistent management: A single platform for managing diverse cloud environments simplifies operations and reduces complexity.
3. Cost optimization: Ability to move workloads to the most cost-effective environment based on changing needs.
4. Enhanced security and compliance: Unified security policies across all environments, facilitating regulatory compliance.

Common use cases for hybrid multicloud solutions include:

1. Application modernization and DevOps: Enabling rapid development and deployment across multiple environments.
2. Disaster recovery and business continuity: Leveraging multiple clouds for robust backup and recovery strategies.
3. Edge computing and IoT: Combining edge processing with centralized cloud resources for IoT applications.
4. Data analytics: Utilizing diverse cloud resources for big data processing and AI/ML workloads.

V. Hybrid Cloud and Artificial Intelligence

The convergence of hybrid cloud infrastructure and artificial intelligence (AI) is creating new opportunities for organizations to leverage advanced analytics and machine learning capabilities while maintaining control over sensitive data and processes [9].

AI-Driven Resource Optimization

Building on the concept of cost optimization [6], AI systems can predict resource needs across public and private cloud environments. These intelligent systems dynamically allocate resources, optimizing both cost and performance in real-time. This approach ensures efficient utilization of hybrid cloud resources, similar to how AI optimizes healthcare resource allocation.

Intelligent Security in Hybrid Environments

Extending beyond traditional security measures, AI-powered security systems can detect and respond to threats across hybrid cloud infrastructures in real-time. These systems continuously learn and adapt to new attack patterns, providing robust protection for sensitive data and applications distributed across various cloud environments [4].

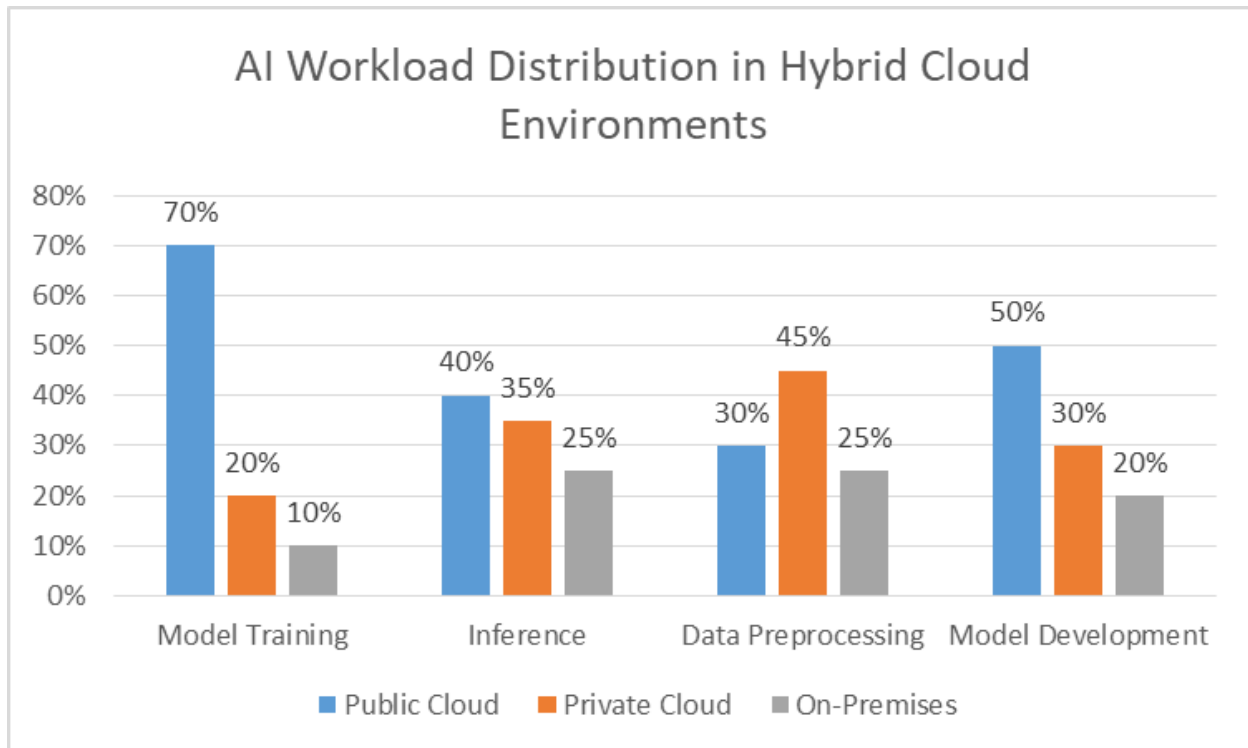


Fig. 2: AI Workload Distribution in Hybrid Cloud Environments [9, 10]

AI for Hybrid Cloud Management

Similar to virtual health assistants in healthcare, AI-powered chatbots or virtual assistants can help IT teams manage complex hybrid cloud environments. These intelligent assistants can troubleshoot issues, provide insights, and even perform routine tasks, significantly improving operational efficiency [11].

Machine Learning for Workload Placement

Analogous to personalized medicine approaches, machine learning algorithms can analyze workload characteristics to determine the optimal environment (public cloud, private cloud, or on-premises) for each application. This ensures that each workload runs in the most suitable environment, maximizing performance and cost-effectiveness [5].

Natural Language Processing for Cloud Operations

NLP technologies can be applied to analyze logs, incident reports, and documentation across hybrid cloud environments. This application of AI can improve operations, enhance troubleshooting processes, and provide valuable insights for optimizing hybrid cloud architectures [9].

AI-Enhanced Edge Computing in Hybrid Clouds

Leveraging concepts similar to AI in medical imaging, edge computing enhanced by AI can process data locally within hybrid cloud architectures. This approach reduces latency and improves real-time decision-making, particularly beneficial for IoT applications and data-intensive workloads [12].

These advanced AI applications in hybrid cloud environments demonstrate the potential for significant improvements in efficiency, security, and decision-making. As organizations continue to adopt and refine these technologies, the synergy between AI and hybrid cloud infrastructure will likely drive further innovations in cloud computing and data management strategies.

AI-Powered Hybrid Multicloud Management

Both Nutanix and VMware are incorporating AI and machine learning into their hybrid multicloud platforms to enhance management capabilities [14]. These AI-driven features include:

1. Intelligent workload placement: AI algorithms determine the optimal environment for each workload based on performance, cost, and compliance requirements.
2. Predictive analytics for capacity planning: ML models forecast resource needs, enabling proactive scaling and cost management.
3. Automated troubleshooting and self-healing: AI-powered systems detect and resolve issues across hybrid environments, minimizing downtime.

VI. Impact on IT and Tech Landscape

The adoption of hybrid cloud infrastructure is profoundly reshaping the IT and technology landscape, offering organizations unprecedented flexibility, efficiency, and innovation potential. This shift is further complemented by emerging paradigms such as edge-centric computing, which extends the capabilities of hybrid cloud environments [11].

Versatility of hybrid cloud solutions

Hybrid cloud solutions provide a versatile framework that allows organizations to:

- Tailor their IT infrastructure to specific business requirements
- Seamlessly integrate legacy systems with modern cloud services
- Adapt quickly to changing market conditions and technological advancements
- Support a wide range of applications, from traditional enterprise software to cutting-edge microservices architectures
- Leverage edge computing capabilities for improved performance and reduced latency

This versatility enables businesses to modernize their IT infrastructure gradually, minimizing disruption while maximizing the benefits of cloud and edge technologies.

AI technologies further enhance this versatility by enabling intelligent, context-aware resource allocation and workload placement across hybrid environments. This AI-driven approach allows organizations to dynamically adapt their hybrid cloud configurations to changing business needs and technological advancements.

Cost-effectiveness and resource optimization

Hybrid cloud adoption drives cost-effectiveness and resource optimization through:

- Dynamic allocation of resources based on actual demand
- Reduction in over-provisioning of on-premises infrastructure
- Improved utilization of existing IT assets
- Access to pay-as-you-go pricing models for cloud services
- Efficient data processing at the edge, reducing data transfer costs and improving response times

Organizations can achieve significant cost savings while maintaining the ability to scale resources up or down as needed, leading to more efficient IT operations and better alignment of IT spending with business objectives.

AI-driven optimization takes this cost-effectiveness to new levels. Machine learning algorithms can predict resource needs, automate scaling, and optimize workload placement across hybrid environments, ensuring maximum efficiency and minimum waste of resources.

Enhanced security frameworks

Hybrid cloud environments are driving the development of more sophisticated and comprehensive security frameworks:

- Integration of on-premises and cloud-based security solutions
- Implementation of zero-trust security models across hybrid environments
- Advanced data encryption and access control mechanisms
- Improved visibility and monitoring across diverse IT ecosystems

These enhanced security frameworks enable organizations to maintain robust protection for their data and applications while leveraging the benefits of cloud services.

AI is revolutionizing security in hybrid cloud environments by enabling real-time threat detection, automated incident response, and predictive analytics for potential vulnerabilities. These AI-powered security measures provide a more robust and adaptive defense against evolving cyber threats.

Support for diverse business needs

The flexibility of hybrid cloud infrastructure allows it to support a wide range of business needs:

- Enabling digital transformation initiatives across various industries
- Supporting remote work and distributed teams through cloud-based collaboration tools
- Facilitating rapid prototyping and deployment of new products and services
- Enabling advanced analytics and AI capabilities for data-driven decision making

This adaptability makes hybrid cloud an essential foundation for organizations looking to innovate and stay competitive in rapidly evolving markets.

Acceleration of innovation

Hybrid cloud environments are accelerating innovation by:

- Providing access to cutting-edge cloud services and technologies
- Enabling faster development and deployment of new applications
- Facilitating experimentation and testing of new ideas with minimal risk
- Supporting agile and DevOps methodologies through integrated development and operations environments

The ability to rapidly prototype, test, and scale new solutions is giving organizations a significant advantage in bringing innovative products and services to market [12].

Evolving Hybrid Multicloud Ecosystem

The hybrid multicloud landscape is rapidly evolving, with Nutanix and VMware driving innovation in this space [14]. Key trends include:

1. Increased focus on cloud-native technologies: Adoption of containerization and microservices architectures for greater portability across clouds.
2. Enhanced data mobility: Solutions that facilitate seamless data movement and access across diverse cloud environments.
3. Emphasis on cloud financial management: Tools for optimizing costs across multiple cloud providers and on-premises infrastructure.

These developments, spearheaded by companies like Nutanix and VMware, are reshaping how organizations approach their cloud strategies, enabling more flexible, efficient, and innovative IT infrastructures.

CONCLUSION

The growing significance of hybrid cloud infrastructure in modern IT landscapes represents a pivotal shift in how organizations approach their technology strategies. As this paper has explored, hybrid cloud solutions offer a compelling blend of flexibility, scalability, and cost-effectiveness that is reshaping industries from healthcare to finance and beyond. The synergy between hybrid cloud and emerging technologies like artificial intelligence is unlocking new possibilities for innovation and operational

efficiency. However, the adoption of hybrid cloud is not without challenges, particularly in areas of security, compliance, and integration. Despite these hurdles, the benefits of hybrid cloud – including improved resource optimization, enhanced disaster recovery capabilities, and support for diverse business needs – make it an increasingly attractive option for organizations of all sizes. As we look to the future, the continued evolution of hybrid cloud technologies promises to further accelerate digital transformation efforts and drive innovation across the global business landscape. Organizations that successfully navigate the complexities of hybrid cloud adoption are likely to gain a significant competitive advantage in an increasingly digital-first world. The hybrid cloud model, therefore, is not just a technological trend, but a fundamental reimagining of IT infrastructure that will continue to shape the future of business and technology for years to come.

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