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Cloud Computing in Government

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ABSTRACT

Cloud computing refers to the delivery of computing services over the Internet, allowing government agencies to access shared resources without the need for extensive physical infrastructure. It is transforming government operations by enhancing efficiency, security, and service delivery through strategic adoption of cloud technologies, helping agencies meet their goals while optimizing costs. A lot of governments are moving toward cloud, and many are using a hybrid approach. The benefits of cloud computing for government agencies are substantial and specific. For forward-thinking government leaders, additional value lies in cloud's ability to accelerate the integration of transformative technologies like artificial intelligence, which is a priority for governments across the world. This paper examines the adoption and implementation cloud computing in the government context.

KEYWORDS: *technology, cloud, cloud computing, government, public service.*

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INTRODUCTION

Government agencies are under growing pressure to modernize. Aging infrastructure, budget constraints, and rising expectations from citizens make it harder to deliver essential services efficiently. Cloud technology offers a path forward, although the transition to the cloud has not been easy. Most government agencies recognize the benefits of moving to the cloud, but key challenges like budget, security, and compliance are slowing adoption. From websites to mission-critical apps, the cloud is helping government agencies accomplish things they never thought possible. The US federal government has been migrating to the cloud for a long time. As governments around the world strive to operate more efficiently while modernizing and improving service delivery, many are turning to cloud computing as a strategic enabler. The digital transformation across government agencies has reached a pivotal moment, with cloud computing emerging as a critical driver. A cloud-based solution can help public agencies effectively respond to client demands even during peak periods. One of the key enablers for this transition to digital is cloud computing technology, which helps deliver government services in a more agile, faster, and cheaper manner compared with a traditional information technology infrastructure [1].

The advent of new technologies has increased cloud computing adoption in private and public institutions (government) and raised the demand for communication and access to a shared pool of resources and storage capabilities. Governments across the globe are moving to the cloud to improve services, reduce costs, and increase effectiveness and efficiency while fostering innovation and citizen engagement. Federal, state, and local government agencies are now migrating to a cloud environment to host the critical business processes that support their mission objectives. Cloud computing is reshaping the landscape of government operations, offering significant benefits while also presenting challenges that need to be addressed for successful implementation. It is transforming government operations by enhancing efficiency, enabling AI-driven innovation and breaking down data silos – helping agencies meet their goals while optimizing costs. The shift from on-premises infrastructure to cloud-based solutions is unlocking a range of benefits, from cost savings to enhanced data-sharing

and collaboration. This transition means a shift from a capital to an operational expense, which can be a significant advantage for cash-strapped government agencies, allowing them to manage their budgets more flexibly, avoid large upfront costs, and generate additional savings through efficient management. Cloud computing in government IT is more than a trend; it's a strategic investment in the future [2].

CLOUD COMPUTING BASICS

Cloud computing represents a newly emerging service-oriented computing technology. It is the provision of scalable computing resources as a service over the Internet. It allows manufacturers to use many forms of new production systems such as 3D printing, high-performance computing (HPC), industrial Internet of things (IIoT), and industrial robots. It is transforming virtually every facet of modern manufacturing. It is innovating, reducing cost, and bolstering the competitiveness of American manufacturing [3]. Figure 1 shows the symbol for cloud computing [4]. Some features of cloud computing are displayed in Figure 2 [5].

The key characteristic of cloud computing is the virtualization of computing resources and services. Cloud computing is implemented in one of three major formats: software as a service (SAAS), platform as a service (PAAS), or infrastructure as a service (IAAS). These services are explained as follows:

SaaS: This is a software delivery model in which software and associated data are hosted on the cloud. In this model, cloud service providers offer on-demand access to computing resources such as virtual machines and cloud storage.

PaaS allows the end-user to create a software solution using tools or libraries from the platform service provider. In this model, cloud service providers deliver computing platforms such as programming and execution.

In the IaaS model, cloud service providers can rent manufacturing equipment such as 3D printers.

Just like cloud computing, CM services can be categorized into three major deployment models (public, private, and hybrid clouds) [6]:

- Private cloud refers to a centralized management effort in which manufacturing services are shared within one company or its subsidiaries. A private cloud is often used exclusively by one organization, possibly with multiple business units.
- Public cloud realizes the key concept of sharing services with the general public. Public clouds are commonly implemented through data centers operated by providers such as Amazon, Google, IBM, and Microsoft.
- Hybrid cloud that spans multiple configurations. and is a composed of two or more clouds (private, community or public), offering the benefits of multiple deployment modes.

These services and models are shown in Figure 3 [1]. Cloud computing finds application in almost every field.

CLOUD COMPUTING IN GOVERNMENT

Technology has revolutionized the way we communicate, stay informed, entertain ourselves, and live. But it has also impacted how government manages operations and services. Technology is not only a tool, but also a driver of change and improvement for government. Government can harness technology, such as artificial intelligence and cloud computing, to improve its operations and optimize processes and resources by automating, simplifying, and speeding up administrative tasks, reducing costs, errors, and response times [7]. Government agencies at all levels, federal, state, and local, are rapidly adopting cloud computing to address the changing needs and the challenges of their legacy IT systems.

The term "cloud" is often used broadly in the Federal Government for any technology solution provided by an outside vendor. To realize the full benefit of cloud technology, government agencies must cultivate an organizational mindset of constant improvement and learning. Modernization is a constant state of change and part of the day-to-day business of technology at every agency. Agencies will need to iteratively improve policies, technical guidance, and business requirements to match changing needs, drive positive outcomes, and prevent their IT portfolio from becoming obsolete. Figure 4 shows a representation of cloud computing in government [7].

The private sector has identified several leading practices for adopting cloud computing solutions. When adopting and implementing cloud computing solutions, the following leading three practices across management areas—acquisition, cybersecurity, and workforce development—are recommended. These leading practices are illustrated in Figure 5 and explained as follows [8]:

- *Acquisition:* Companies reported using some leading practices, including defining the business case for the cloud adoption, negotiating clear terms and agreements, and assessing service performance against expectations.

- *Cybersecurity:* Companies reported using some leading practices, including implementing incident response procedures, establishing continuous monitoring, and clarifying cloud security responsibilities.
- *Workforce Development*: Companies reported using some leading practices, including identifying skill gaps, retaining and recruiting staff, and shifting internal culture.

APPLICATIONS OF CLOUD COMPUTING IN GOVERNMENT

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. It is changing the way computing is undertaken. The adoption of cloud computing by government agencies is moving forward, with a focus on leveraging the benefits of cloud technology to modernize and improve government services. As government agencies transition to the cloud, they are discovering clear and measurable benefits that go far beyond modernization. Common applications of cloud computing in government include the following [9,10]:

- *Cloud Smart*: The Cloud Smart strategy was developed by the US government. Developed nearly a decade after its predecessor (Cloud First), Cloud Smart equips agencies with actionable information and recommendations gleaned from some of the country's most impactful public and private sector use cases. Its aims is to accelerate the adoption of cloud-based solutions across federal agencies. This strategy is built on three key pillars: security, procurement, and workforce. Collectively, these elements embody the interdisciplinary approach to IT modernization that the Federal enterprise needs. The Cloud Smart Strategy encourages agencies to think of cloud as an array of solutions that offer many capabilities and management options to enhance mission and service delivery.
- Critical to the success of the security strategy in the context of Cloud Smart is the assurance of confidentiality, integrity, and availability of Federal information as it traverses networks and rests within system.
- *Service Level Agreements:* A Service Level Agreement (SLA) between a customer and a service provider defines the level of performance expected from a service provider. While not standardized in the Federal Acquisition Regulation (FAR), SLAs are incorporated through contract clauses and quality assurance contractual provisions. In legacy technology environments, these agreements represent a critical element of negotiation with suppliers. Such governance, architecture, and operational clarity would help ensure that services are performed as intended, and, when paired with the right SLA language, would offer agencies a way to mitigate risk while optimizing the performance and efficiency of their newly procured cloud-based solution.
- *Workforce:* The Federal IT workforce plays an integral role in the execution of agency missions, delivery of services to the public, and provision of security to the nation's essential systems and information. Government agencies' cloud strategies and policies should include a workforce development and planning component that tailors a transformation and training approach to that agency. As agencies adopt and migrate to cloud platforms, the impact that these migrations have on the Federal workforce needs to be examined. Agencies should identify potential skills gaps that emerge as a result of a transition to cloud-based services.

BENEFITS

The benefits of the cloud are too significant to ignore. The benefits are clear: from cost savings to enhanced service delivery, cloud technology offers a pathway to a more connected and responsive government. Cloud computing enables on-demand access to shared computing resources, providing services more quickly and at a lower cost than having agencies maintain these resources themselves. Government agencies are increasingly adopting cloud computing solutions to enhance efficiency, accessibility, and security. Other benefits of cloud computing in government include the following [9,11,12]:

- *Cost efficiency*: This is a major driver. It eliminates the need for costly hardware upgrades, reduces IT maintenance, and lowers total cost of ownership over time. Agencies can also scale services as needed and pay only for what they use, freeing up both budget and staff resources. By transitioning to cloud services, agencies can reduce the costs associated with maintaining physical infrastructure and improve budget efficiency. Transitioning to cloud services will allow government agencies to reduce significant upfront expenses and shift to more predictable and manageable operational costs. This move will

significantly improve budget forecasting and resource allocation.

- *Data Security*: Information security and privacy concerns raised in the past remain significant to government adoption and utilization of cloud computing. The move to the cloud significantly enhances data security. Providers like Microsoft Azure offer advanced encryption features and robust cybersecurity frameworks, ensuring that government data and citizen information are protected by the most stringent security standards. This addresses a critical concern in public sector IT, offering peace of mind that sensitive data is safeguarded against evolving threats.
- *Data Sharing:* Governments have typically been plagued with silos of data, where you have different departments or agencies within a government holding on to information and not sharing it with their peers. Cloud adoption is helping to break down data silos by centralizing data storage and access for different departments or teams within an organization. Improved data-sharing has been identified as key to tackling major challenges that are common across governments, such as boosting economic growth, reducing carbon emissions, and improving healthcare. Data sharing becomes an opportunity to foster communication across departments and to be able to tackle problems in new and refreshing ways.
- *Scalability:* Cloud services provide the ability and flexibility needed to scale IT resources, especially with changing demands in a changing environment. These changes include public emergency emergencies, seasonal traffic, and new technology or integrations. Managed cloud services allow for seamless adjustments that are easily manageable. Agencies benefit from scalability and flexibility, gaining the ability to respond quickly to evolving needs without massive infrastructure overhauls. Whether it is adjusting capacity during emergencies or rolling out new services, the cloud adapts in real time. Federal agencies are increasingly employing secure and scalable cloud solutions to transform how the government operates.
- *Compliance:* Government entities follow strict federal, state, and local regulations that are essential for government IT operations. Managed services offer the continual compliance monitoring needed, along with advanced security protocols and adherence to FedRAMP, StateRAMP, and NIST guidelines, ensuring that private and sensitive data remains secure and protected.
- *Citizen Experience*: The cloud improves the citizen experience. With faster, more reliable services and user-friendly access, agencies can provide better transparency and responsiveness to their communities. Cloud technology is not just a tech upgrade, it is a smarter way to serve. Cloud computing enables faster access to IT resources, allowing agencies to respond more quickly to public needs and improve overall service quality.
- *Human Productivity:* A high level of productivity and accessibility is crucial for governments looking to maximize the value of their cloud and AI investments. It is not just about convenience and efficiency of your staff. Everybody needs to be assessing the software that they acquire and the platforms that they use in light of their cloud spend. Governments can accelerate innovation, improve collaboration, and optimize their technology investments – all while delivering better services to citizens.

CHALLENGES

In spite of the benefits, government organizations face several challenges in fully realizing the potential of cloud computing. As the federal government transitions to cloud computing, agencies face challenges in four areas: ensuring cybersecurity, procuring cloud services, maintaining a skilled workforce, and tracking costs and savings. Budget remains a primary concern, especially for those with tight constraints. Other challenges of cloud computing in government include the following [9,13,14]:

- *Ensuring Cybersecurity:* It is essential that agencies consider and manage security and privacy risk to information and mission services when making cloud procurement and deployment decisions. Ensuring the security of cloud services remains a top priority, as agencies must protect sensitive information from cyber threats. Agencies should take a risk-based approach to securing cloud environments. This requires that agencies place an emphasis on protections at the data layer in addition to the network and physical infrastructure layers. Assembling a cadre of professionals and providing direct engagement with all aspects of the security authorization process will build a common and comprehensive understanding of cloud security.
- *Skilled Workforce*: Successful adoption of cloud solutions requires a workforce that understands how to manage the complexities of a migration as

well as how to support a cloud environment once fully deployed. Having skilled IT personnel is key to supporting the federal government's cloud adoption. Agencies are strongly encouraged to leverage industry projections to help predict future workforce skill and position requirements, especially for IT roles. Current employees may lack the skills or knowledge required to facilitate a cloud migration or to maintain the environment once migrated. Agencies should develop employee reskilling strategies that focus on training and professional development opportunities. It is recommended that the Coast Guard, Department of Defense, and the Department of State take actions by updating their strategic plans to address the workforce issues related to cloud computing. Figure 6 shows a cloud computing workforce [13].

- *Procuring Cloud Services:* An important part of procuring cloud services is incorporating a service level agreement into the contract. These agreements define the level of service and performance that the agency expects the contractor to meet. For example, the agencies do not always specify what constitutes a security breach and the responsibilities for notifying the agency.
- *Transparency:* Government organizations are under pressure from legislative bodies to increase public access to certain collections of government data in order to increase transparency and improve citizen experiences.
- *Collaboration*: Successfully managing cloud adoption risks requires collaboration between agency leadership, mission owners, technology practitioners, and governance bodies. Coordination between information security and privacy programs is necessary to ensure compliance with applicable privacy requirements and for the successful identification and management of risks.
- *Tracking Costs and Savings:* Federal policies and guidance have stressed the importance of reducing acquisition and operating costs by purchasing cloud services through the adoption of cloud computing. For example, federal agencies were often using inconsistent data to calculate cloud spending and were not clear about the costs they were required to track. In addition, agencies had difficulty in systematically tracking savings data and expressed that OMB guidance did not require them to explicitly report savings from cloud implementations.
- *Regulations:* Cloud computing regulations encompass a range of legal frameworks aimed at governing the use of cloud technology by organizations and consumers. They are vital for ensuring the security, privacy, and accountability of digital services. They establish legal frameworks that govern how data is managed, stored, and shared, thereby fostering trust between cloud service providers and users. The regulations play a crucial role in ensuring compliance, data security, and user privacy within this dynamic technological landscape. In a globalized digital economy, understanding the significance of cloud computing regulations allows businesses to navigate complex legal landscapes, ensuring compliance and promoting data integrity across jurisdictions. Cloud providers face significant compliance challenges due to the complex landscape of regulations governing data privacy and protection. Governments play a pivotal role in shaping cloud computing regulations to ensure security, privacy, and compliance within the digital landscape. Internationally, government collaboration on cloud computing regulations is increasingly necessary due to the cross-border nature of data.

CONCLUSION

Government agencies are increasingly adopting hybrid cloud solutions and migrating existing workloads to the cloud. As cloud technology continues to evolve, it is expected to play a crucial role in modernizing government services and improving citizen engagement. By taking these actions to expand the options available to agencies to secure their networks and data, the collective ability of the Federal Government is heightened, as its effectiveness in managing risk. By leveraging modern technologies and practices, agencies will be able to harness new capabilities and expand existing abilities to enable their mission and deliver services to the public faster.

Government agencies should assess their requirements and seek the environments and solutions, cloud or otherwise, that best enable them to achieve their mission goals while being good stewards of taxpayer resources. They must also track their growth in areas where decisions about technology intersect other disciplines. More information about cloud computing in the government can be found in the books [15-22] and the following related journals:

- Journal of Cloud Computing
- IEEE Cloud Computing
- IEEE Transactions on Cloud Computing

- International Journal of Cloud Applications and Computing
- International Journal of Cloud Computing and Services Science
- i-manager's Journal on Cloud Computing

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Figure 1 The symbol for cloud computing [4].

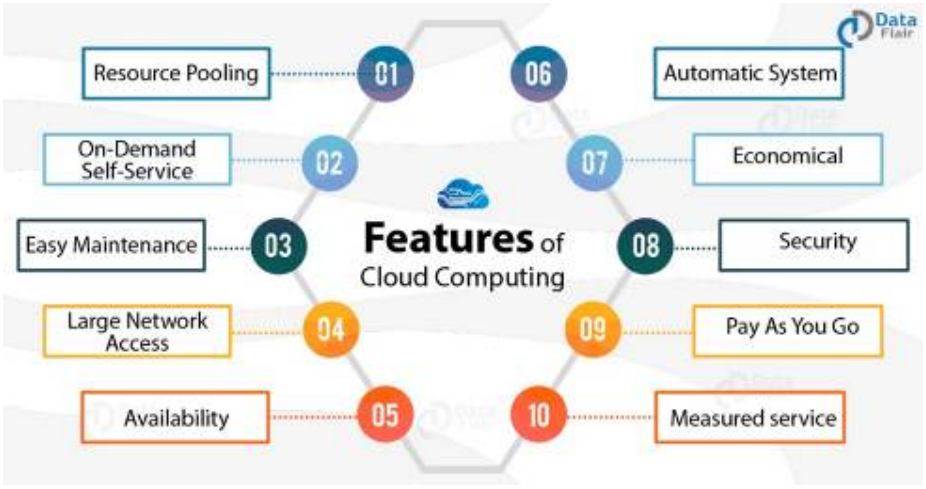

Figure 2 Some features of cloud computing [5].

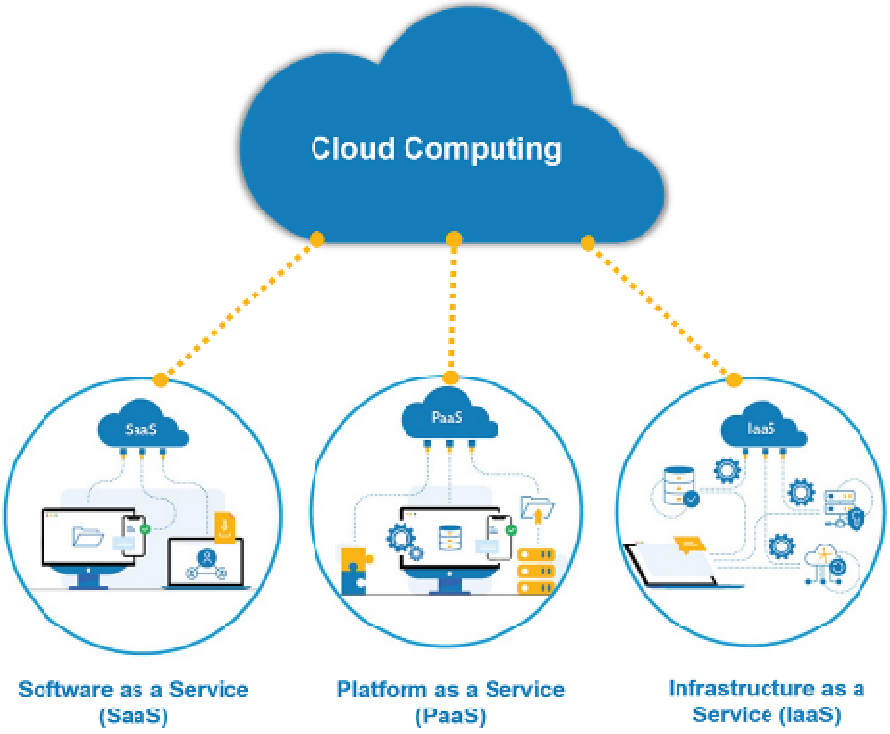

Figure 3 Cloud computing services and models [1].

Figure 4 A representation of cloud computing in government [7].

Figure 5 Leading practices for adopting cloud services [8].

Figure 6 A cloud computing workforce [13].