

Security and Privacy of Cloud Data Auditing Protocols: A Review, State-of-the-art, Open Issues, and Future Research Directions

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Abstract—Cloud service providers offer a trustworthy and resistant-based storage environment for on-demand cloud services to outsource clients' data. Several researchers and business entities currently adopt cloud services to store their data in remote cloud storage servers for cost-saving purposes. Cloud storage offers numerous advantages to users like scalability, low capital expenses, and data available from any place, anytime, regardless of location and device. However, as the users lose physical access and control over data, the storage service raises security and privacy issues, such as confidentiality, integrity, and availability of outsourced data. Data integrity is a primary concern for cloud users to confirm whether data integrity is intact or not. This paper presents a comprehensive review of cloud data auditing schemes and a comparative analysis of the desirable features. Furthermore, it provides advantages and disadvantages of the state-of-the-art techniques and a performance comparison regarding the communicational and computational costs of involved entities. It also highlights desirable features of different techniques, open issues, and future research trends of cloud data auditing protocols.

Keywords—Cloud computing; proof of possession; data integrity auditing; proof of retrievability; public auditing; proof of ownership

I. INTRODUCTION

Cloud computing is a new, rapidly emerging technology paradigm [1, 2], which can resolve large-scale service issues in multiple industries, such as engineering, sciences, and e-commerce [3]. Currently, several Cloud Service Providers (CSPs), for example, Linode [4], Amazon EC2 [5], Google Cloud Platform [6], and Microsoft Azure [7], manage and distribute shared resources for cloud users [8, 9]. Cloud computing offers manageable shared resources like services, networks, servers, applications, and storage that can be accessed over the Internet and managed with minimal effort without the interaction of cloud service providers [10, 11]. Generally, the distributed shared resources of the CSPs are available to their clients based on the pay-as-you-go. The CSPs mainly offer services like Platform-as-a-Service, Software-as-a-Service, and Infrastructure-as-a-Service [12, 13], as shown in Fig. 1. The web applications we used years ago, for instance, YouTube, Facebook, Instagram, and Twitter, are examples of cloud computing services. Furthermore, Dropbox, Amazon web services, and Google applications are generally utilized for

personal and business purposes to store and share information anywhere and anytime via the Internet.

The critical part of this business model is to outsource and share data for distributed computing. Cloud storage is an elastic on-demand service model that attains significant benefits; for example, it decreases storage administration burden and reduces infrastructure and software costs. Moreover, it helps to access data from various geographic locations, focusing on ease of maintenance, efficient computation [14], data storage, data archival disaster recovery, etc. [15]. Statista reported that the cloud computing business model persistently develops and is estimated to reach 379 billion US dollars by 2022, showing a tremendous increase in this service sector [16].

Even though the adoption and development of cloud computing businesses are growing every year, most corporations are not satisfied with using this business model due to some obstacles, like pricing, interoperability, vendor lock-in, reliability, and security [17]. Security is the most critical concern [17] because it can be compromised while transferring the data from one location to another by cloud administrators, dishonest CSPs, malware, or other malevolent users who can mutilate the data [18].



Fig. 1. Service-oriented architecture of cloud computing.

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Cyber Security and Privacy Control Robert R. Moeller, 2011-04-12 This section discusses IT audit cybersecurity and privacy control activities from two focus areas First is focus on some of the many cybersecurity and privacy concerns that auditors should consider in their reviews of IT based systems and processes Second focus area includes IT Audit internal procedures IT audit functions sometimes fail to implement appropriate security and privacy protection controls over their own IT audit processes such as audit evidence materials IT audit workpapers auditor laptop computer resources and many others Although every audit department is different this section suggests best practices for an IT audit function and concludes with a discussion on the payment card industry data security standard data security standards PCI DSS a guideline that has been developed by major credit card companies to help enterprises that process card payments prevent credit card fraud and to provide some protection from various credit security vulnerabilities and threats IT auditors should understand the high level key elements of this standard and incorporate it in their review where appropriate **Audit and Compliance** Texas State University--San Marcos, 2005 Auditing Information and Cyber Security Governance Robert E. Davis, 2021-09-22 A much needed service for society today I hope this book reaches information managers in the organization now vulnerable to hacks that are stealing corporate information and even holding it hostage for ransom Ronald W Hull author poet and former professor and university administrator A comprehensive entity security program deploys information asset protection through stratified technological and non technological controls Controls are necessary for counteracting threats opportunities and vulnerabilities risks in a manner that reduces potential adverse effects to defined acceptable levels This book presents a methodological approach in the context of normative decision theory constructs and concepts with appropriate reference to standards and the respective guidelines Normative decision theory attempts to establish a rational framework for choosing between alternative courses of action when the outcomes resulting from the selection are uncertain Through the methodological application decision theory techniques can provide objectives determination interaction assessments performance estimates and organizational analysis A normative model prescribes what should exist according to an assumption or rule

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