

Cloud Security risks and countermeasures

Upma Jain

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In general terms, security controls in cloud computing are similar to the security controls in any IT environment. However, because of the operational models and technologies used to enable cloud service, cloud computing may present risks that are specific to the cloud environment. The essential concept in this regard is that the enterprise loses a substantial amount of control over resources, services, and applications but must maintain accountability for security and privacy policies.

The Cloud Security Alliance [CSA10] lists the following as the top cloud-specific security threats, together with suggested countermeasures:

- **Abuse and nefarious use of cloud computing:** For many CPs, it is relatively easy to register and begin using cloud services, some even offering free limited trial periods. This enables attackers to get inside the cloud to conduct various attacks, such as spamming, malicious code attacks, and denial of service. PaaS providers have traditionally suffered most from this kind of attacks; however, recent evidence shows that hackers have begun to target IaaS vendors as well. The burden is on the CP to protect against such attacks, but cloud service clients must monitor activity with respect to their data and resources to detect any malicious behavior.

Countermeasures include (1) stricter initial registration and validation processes; (2) enhanced credit card fraud monitoring and coordination; (3) comprehensive introspection of customer network traffic; and (4) monitoring public blacklists for one's own network blocks.

- **Insecure interfaces and APIs:** CPs expose a set of software interfaces or APIs that customers use to manage and interact with cloud services. The security and availability of general cloud services are dependent upon the security of these basic APIs. From authentication and access control to encryption and activity monitoring, these interfaces must be designed to protect against both accidental and malicious attempts to circumvent policy.

Countermeasures include (1) analyzing the security model of CP interfaces; (2) ensuring that strong authentication and access controls are implemented in concert with encrypted transmission; and (3) understanding the dependency chain associated with the API.

- **Malicious insiders:** Under the cloud computing paradigm, an organization relinquishes direct control over many aspects of security and, in doing so, confers an unprecedented level of trust onto the CP. One grave concern is the risk of malicious insider activity. Cloud architectures necessitate certain roles that are extremely high risk. Examples include CP system administrators and managed security service providers.

Countermeasures include the following: (1) enforce strict supply chain management and conduct a comprehensive supplier assessment; (2) specify human resource requirements as part of legal contract; (3) require transparency into overall information security and management practices, as well as compliance reporting; and (4) determine security breach notification processes.

- **Shared technology issues:** IaaS vendors deliver their services in a scalable way by sharing infrastructure. Often, the underlying components that make up this infrastructure (CPU caches, GPUs, etc.) were not designed to offer strong isolation properties for a multi-tenant architecture. CPs typically approach this risk by the use of isolated virtual machines for individual clients. This approach is still vulnerable to attack, by both insiders and outsiders, and so can only be a part of an overall security strategy.

Countermeasures include the following: (1) implement security best practices for installation/configuration; (2) monitor environment for unauthorized changes/activity; (3) promote strong authentication and access control

for administrative access and operations; (4) enforce SLAs for patching and vulnerability remediation; and (5) conduct vulnerability scanning and configuration audits.

- **Data loss or leakage:** For many clients, the most devastating impact from a security breach is the loss or leakage of data. We address this issue in the next subsection.

Countermeasures include the following: (1) implement strong API access control; (2) encrypt and protect integrity of data in transit; (3) analyze data protection at both design and run time; and (4) implement strong key generation, storage and management, and destruction practices.

- **Account or service hijacking:** Account or service hijacking, usually with stolen credentials, remains a top threat. With stolen credentials, attackers can often access critical areas of deployed cloud computing services, allowing them to compromise the confidentiality, integrity, and availability of those services.

Countermeasures include the following: (1) prohibit the sharing of account credentials between users and services; (2) leverage strong two-factor authentication techniques where possible; (3) employ proactive monitoring to detect unauthorized activity; and (4) understand CP security policies and SLAs.

- **Unknown risk profile:** In using cloud infrastructures, the client necessarily cedes control to the CP on a number of issues that may affect security. Thus the client must pay attention to and clearly define the roles and responsibilities involved for managing risks. For example, employees may deploy applications and data resources at the CP without observing the normal policies and procedures for privacy, security, and oversight.

Countermeasures include (1) disclosure of applicable logs and data; (2) partial/full disclosure of infrastructure details (e.g., patch levels and firewalls); and (3) monitoring and alerting on necessary information.

Data Protection in Cloud

As can be seen from the previous section, there are numerous aspects to cloud security and numerous approaches to providing cloud security measures. A further example is seen in the NIST guidelines for cloud security, specified in SP-800-14 and listed in Table 5.3. Thus, the topic of cloud security is well beyond the scope of this chapter. In this section, we focus on one specific element of cloud security.

There are many ways to compromise data. Deletion or alteration of records without a backup of the original content is an obvious example. Unlinking a record from a larger context may render it unrecoverable, as can storage on unreliable media. Loss of an encoding key may result in effective destruction. Finally, unauthorized parties must be prevented from gaining access to sensitive data.

Data Protection in Cloud

Table 5.3 NIST Guidelines on Security and Privacy Issues and Recommendations

Governance

Extend organizational practices pertaining to the policies, procedures, and standards used for application development and service provisioning in the cloud, as well as the design, implementation, testing, use, and monitoring of deployed or engaged services.

Put in place audit mechanisms and tools to ensure organizational practices are followed throughout the system life cycle.

Compliance

Understand the various types of laws and regulations that impose security and privacy obligations on the organization and potentially impact cloud computing initiatives, particularly those involving data location, privacy and security controls, records management, and electronic discovery requirements.

Review and assess the cloud provider's offerings with respect to the organizational requirements to be met and ensure that the contract terms adequately meet the requirements.

Ensure that the cloud provider's electronic discovery capabilities and processes do not compromise the privacy or security of data and applications.

Trust

Ensure that service arrangements have sufficient means to allow visibility into the security and privacy controls and processes employed by the cloud provider, and their performance over time.

Establish clear, exclusive ownership rights over data.

Institute a risk management program that is flexible enough to adapt to the constantly evolving and shifting risk landscape for the life cycle of the system.

Continuously monitor the security state of the information system to support ongoing risk management decisions.

Architecture

Understand the underlying technologies that the cloud provider uses to provision services, including the implications that the technical controls involved have on the security and privacy of the system, over the full system life cycle and across all system components.

Identity and access management

Ensure that adequate safeguards are in place to secure authentication, authorization, and other identity and access management functions, and are suitable for the organization.

Software isolation

Understand virtualization and other logical isolation techniques that the cloud provider employs in its multi-tenant software architecture, and assess the risks involved for the organization.

Data protection

Evaluate the suitability of the cloud provider's data management solutions for the organizational data concerned and the ability to control access to data, to secure data while at rest, in transit, and in use, and to sanitize data.

Take into consideration the risk of collating organizational data with those of other organizations whose threat profiles are high or whose data collectively represent significant concentrated value.

Fully understand and weigh the risks involved in cryptographic key management with the facilities available in the cloud environment and the processes established by the cloud provider.

Availability

Understand the contract provisions and procedures for availability, data backup and recovery, and disaster recovery, and ensure that they meet the organization's continuity and contingency planning requirements.

Ensure that during an intermediate or prolonged disruption or a serious disaster, critical operations can be immediately resumed, and that all operations can be eventually reinstituted in a timely and organized manner.

Incident response

Understand the contract provisions and procedures for incident response and ensure that they meet the requirements of the organization.

Table 5.3 Continued

Ensure that the cloud provider has a transparent response process in place and sufficient mechanisms to share information during and after an incident.
Ensure that the organization can respond to incidents in a coordinated fashion with the cloud provider in accordance with their respective roles and responsibilities for the computing environment.

The threat of data compromise increases in the cloud, due to the number of and interactions between risks and challenges that are either unique to the cloud or more dangerous because of the architectural or operational characteristics of the cloud environment.

Database environments used in cloud computing can vary significantly. Some providers support a **multi-instance model**, which provides a unique DBMS running on a virtual machine instance for each cloud subscriber. This gives the subscriber complete control over role definition, user authorization, and other administrative tasks related to security. Other providers support a **multi-tenant model**, which provides a predefined environment for the cloud subscriber that is shared with other tenants, typically through tagging data with a subscriber identifier. Tagging gives the appearance of exclusive use of the instance, but relies on the CP to establish and maintain a sound secure database environment.

Data must be secured while at rest, in transit, and in use, and access to the data must be controlled. The client can employ encryption to protect data in transit, though this involves key management responsibilities for the CP. The client can enforce access control techniques but, again, the CP is involved to some extent depending on the service model used.

For data at rest, the ideal security measure is for the client to encrypt the database and only store encrypted data in the cloud, with the CP having no access to the encryption key. So long as the key remains secure, the CP has no ability to read the data, although corruption and other denial-of-service attacks remain a risk.

A straightforward solution to the security problem in this context is to encrypt the entire database and not provide the encryption/decryption keys to the service provider. This solution by itself is inflexible. The user has little ability to access individual data items based on searches or indexing on key parameters, but rather would have to download entire tables from the database, decrypt the tables, and work with the results. To provide more flexibility, it must be possible to work with the database in its encrypted form.

An example of such an approach, depicted in Figure 5.10, is reported in [DAMI05] and [DAMI03]. A similar approach is described in [HACI02]. Four entities are involved:

- **Data owner:** An organization that produces data to be made available for controlled release, either within the organization or to external users.
- **User:** Human entity that presents requests (queries) to the system. The user could be an employee of the organization who is granted access to the database via the server, or a user external to the organization who, after authentication, is granted access.
- **Client:** Frontend that transforms user queries into queries on the encrypted data stored on the server.

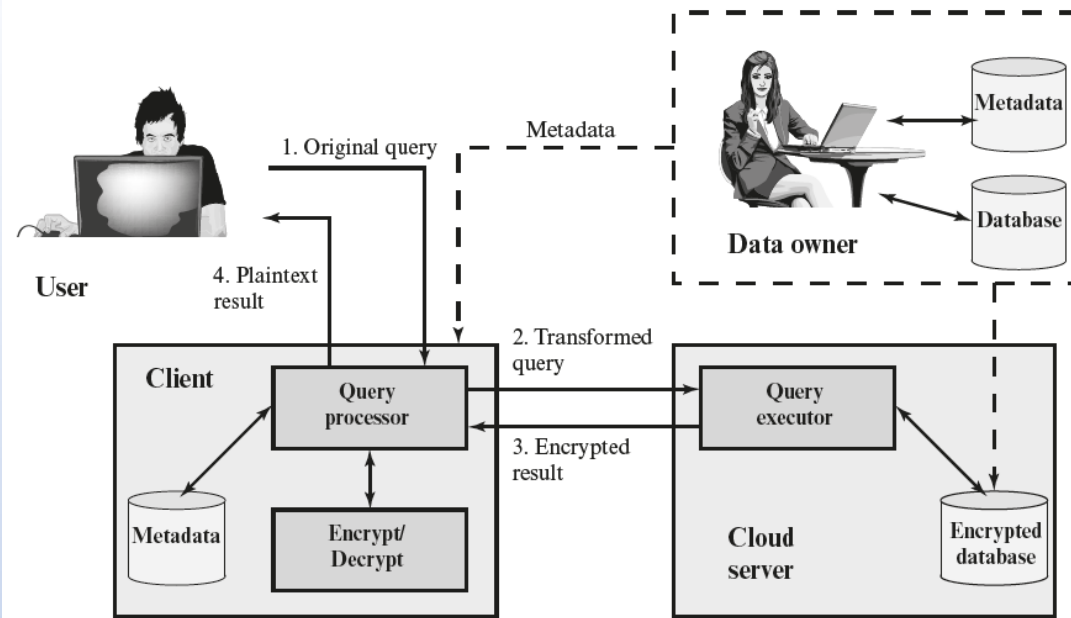


Figure 5.10 An Encryption Scheme for a Cloud-Based Database

- **Server:** An organization that receives the encrypted data from a data owner and makes them available for distribution to clients. The server could in fact be owned by the data owner but, more typically, is a facility owned and maintained by an external provider. For our discussion, the server is a cloud server.

Before continuing this discussion, we need to define some database terms. In relational database parlance, the basic building block is a **relation**, which is a flat table. Rows are referred to as **tuples**, and columns are referred to as **attributes**. A **primary key** is defined to be a portion of a row used to uniquely identify a row in a table; the primary key consists of one or more column names.² For example, in an employee table, the employee ID is sufficient to uniquely identify a row in a particular table.

Let us first examine the simplest possible arrangement based on this scenario. Suppose that each individual item in the database is encrypted separately, all using the same encryption key. The encrypted database is stored at the server, but the server does not have the encryption key. Thus, the data are secure at the server. Even if someone were able to hack into the server's system, all he or she would have access to is encrypted data. The client system does have a copy of the encryption key. A user at the client can retrieve a record from the database with the following sequence:

1. The user issues a query for fields from one or more records with a specific value of the primary key.

2. The query processor at the client encrypts the primary key, modifies the query accordingly, and transmits the query to the server.
3. The server processes the query using the encrypted value of the primary key and returns the appropriate record or records.
4. The query processor decrypts the data and returns the results.

This method is certainly straightforward but is quite limited. For example, suppose the Employee table contains a salary attribute and the user wishes to retrieve all records for salaries less than \$70K. There is no obvious way to do this, because the attribute value for salary in each record is encrypted. The set of encrypted values does not preserve the ordering of values in the original attribute.

There are a number of ways to extend the functionality of this approach. For example, an unencrypted index value can be associated with a given attribute and the table can be partitioned based on these index values, enabling a user to retrieve a certain portion of the table. The details of such schemes are beyond our scope.