Security of Cloud Computing

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INTRODUCTION

Cloud computing is clearly one of today's most enticing technology areas due, at least in part, to its cost-efficiency and flexibility. This technology holds the potential to eliminate the requirements for setting up of excessively expensive computing infrastructure for the IT-based solutions and services that the industry uses. It promises to provide a flexible IT architecture, accessible through Internet for lightweight portable devices.

Cloud computing resources may lie in any corner of the world beyond the reach and control of users, there are multifarious security and privacy challenges that need to be understood and taken care of (Hamdi, 2012). Also, one can never deny the possibility of a server breakdown that has been witnessed, rather quite often in the recent times.

The cost and complexity reduction requirements render the design and development of protection mechanisms even more challenging (Hamdi, 2012). In addition, key design features such as confidentiality, privacy, availability, reliability, resilience, and risk-tolerance are, in some extent, conflicting. The objective of this article is to present the state-of-the-art of cloud security and explore research directions and technology trends to address the protection of cloud communications and networking infrastructures.

BACKGROUND

The Cloud Paradigm

The cloud computing paradigm introduced by the US National Institute for Standards and Technology (NIST) refers to the development and implementation of models for enabling ubiquitous, convenient, on-demand access to a shared set 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. The Cloud Computing is based on five essential characteristics, three service models, and four deployment models.

The Cloud Computing is based on five essential characteristics which are:

- **On-demand self-service:** A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider.
- **Broad network access:** Capabilities are available over the network and accessed through standard mechanisms that promote use by

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heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations).

- **Resource pooling:** The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. Examples of resources include storage, processing, memory, and network bandwidth.
- **Rapid elasticity:** Consumers of cloud resources can flex their use of computer resources (process, storage, bandwidth, and memory) as needed (Winkler, 2011). Capabilities can be elastically provisioned and released to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time.
- **Measured service:** Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service.

Service Models

Cloud computing utilizes three service models by which different types of services are delivered to the end user (Subashini & Kavitha, 2011). The different models have different strengths and are suitable for different customers and business objectives.

- Infrastructure as a Service (IaaS): IaaS provides fundamental computing resources such as processing, storage and network where the client can deploy and run arbitrary software. He needs not own the infrastructure supporting services and does not manage or control it.

Virtualization plays a key role in this process (Kounev & Reinecke, 2012) by having each server host multiple independent virtual machines (VMs) managed by a Virtual Machine Monitor (VMM) often referred to as a Hypervisor.

- **Platform as a Service (PaaS):** PaaS provides a set of programming languages, libraries, services and tools of development for deploying applications created by the customer, who is able to control and manage them. It offers developers a service that provides a complete software development lifecycle management (Subashini & Kavitha, 2011), from planning to design to building applications to deployment to testing to maintenance.
- **Software as a Service (SaaS):** SaaS is a software deployment model where applications are running on a cloud infrastructure and accessible from various client devices. The customer can apply limited user-specific application configuration settings but has no access control or management of the internal infrastructure. The SaaS model offers the customers significant benefits (Subashini & Kavitha, 2011), such as improved operational efficiency and reduced costs.

Deployment Models

There models are offered in four ways depending upon the users' requirements, namely, a public, private, hybrid and community cloud.

- **Public Cloud:** A public cloud provides shared resources owned and managed by a third party over the Internet for the general public. This model offers the greatest level of efficiency but

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