Cloud computing

- Cloud computing = On-demand access to IT capabilities
- Before cloud computing
  - Everything was stored and processed locally (on-premises)
  - Centralized, secluded and segmented
- Now third party (cloud provider) stores the data.

NIST definition of cloud computing

- See also [NIST definition of cloud computing]

Essential characteristics

- **On-demand self-service**
  - Consumers can unilaterally provision computing capabilities
    - E.g. computing power, storage, network
  - Does not require human interaction
- **Broad network access**
  - Capabilities are available and accessible over the network.
  - Via wide variety of platforms e.g. laptops, mobile phones and PDAs
- **Resource pooling**
  - Uses multi-tenant model to provide resources pooled to serve multiple consumers
    - The instances (tenants) are logically isolated, but physically integrated.
    - One or multiple instances of one or multiple applications operate in a shared environment.
  - Assigns different physical and virtual resources dynamically
  - Location is abstracted to e.g. country, state or data-center
    - Exact location is unknown to user
- **Rapid elasticity**
  - Feeling of "infinite" and instant scalability
  - Usually automatically
- **Measured service**
  - Metering capability in an abstracting way e.g. storage, processing, bandwidth, active user accounts.
  - Resource usage can be monitored, controlled, and reported

Cloud computing service models

Infrastructure as a services (IaaS)

- Capability for consumers to provision processing, storage, networks, and other fundamental computing resources
- Aims to give most control over the provided hardware that runs applications
  - E.g. operating systems, storage, and networking components
- E.g. virtual machines (EC2 in Amazon), virtual networks.

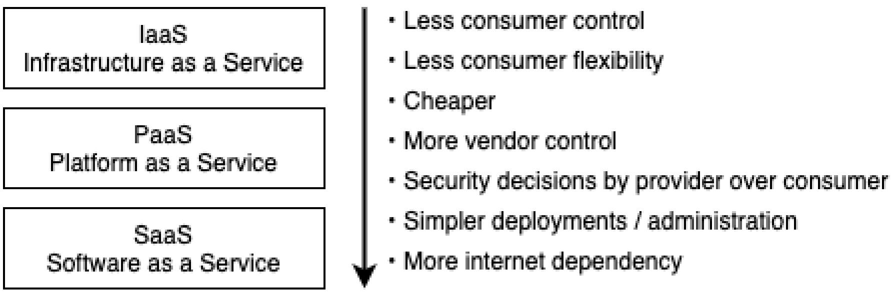
Platform as a Service (PaaS)

- Provides capability for consumers to deploy onto managed cloud infrastructure
- Allows consumer to use programming languages, SDKs, services, and tools supported by the provider
- Consumer does not control or manage underlying cloud infrastructure
  - But can control deployed applications and configurations for the hosting environment
- Provides an environment for building, testing, and deploying software applications
  - Can add features such authentication.
- Aims to help creating an application quickly without managing the underlying infrastructure.
- E.g. development tools, config management, and deployment platforms

Software as a Service (SaaS)

- Software that is centrally hosted and managed for the end customer.
- User does not control underlying cloud architecture
  - E.g. network, servers, OS, storage etc.
  - Can only control limited user-specific application configurations.

IaaS vs PaaS vs SaaS



Identity-as-a-Service (IDaaS)

- Managed authentication services
- Services include e.g. • Single-Sign-On (SSO) • Multi-Factor-Authentication (MFA) • Identity Governance and Administration (IGA) • Access management • Intelligence collection

Security-as-a-Service (SECaaS)

- Integrates security services into corporate infrastructure
- Services include e.g. • penetration testing • authentication • intrusion detection • anti-malware • security and incident management.
- E.g. McAfee Cloud Security

Container-as-a-Service (CaaS)

- Container and cluster services
- Services include e.g. • virtualized container engines • easier container and cluster management
- Inherits features of IaaS and PaaS
- See also container security

Function-as-a-Service (FaaS)

- Provides a platform allowing to develop, run, and manage functionalities without any infrastructure effort.
- E.g. AWS Lambda, Google Cloud Functions, Azure Functions

Separation of duties

- Cloud computing is the ultimate in separation of duties
- E.g.
  - The data owner is the entity accountable for the data itself
  - Data custodian is the entity responsible for access to the data
  - When a single individual becomes both the data owner and the data custodian, security issues can arise.
- Also a countermeasure for insider attacks and social engineering attacks.

Shared responsibility

- **On-premises**: you manage everything.
- **IaaS**: provider manages virtualization, servers, storage and networking
- **PaaS**: provider additionally manages OS, middleware and runtime
- **SaaS**: provider manages everything

Cloud Deployment Models

Private cloud

- Provisioned for exclusive use of single organization
- May be owned/managed/operated by the organization, third party or combination
- May be on or off premises

Public cloud

- No local hardware to manage or keep up-to-date, everything runs on your cloud provider's hardware.
- Services are rendered over a network
- Provisioned for open use by the general public
- May be owned/managed/operated by a business, academic, government or combination.
- Exists on the premises of the cloud provider.

Community Cloud

- Shared infrastructure between several organizations with shared concerns (e.g. compliance)
- Not open to public
- May be owned/managed/operated by the organization, third party or combination
- May be on or off premises

Hybrid cloud

- Composition of two or more cloud (private, community or public)
- Infrastructures remain unique entities
  - but are bound by a technology allowing data and application portability.

Multi cloud

- Multi-cloud is a environment where an organization leverages two or more cloud computing platforms to perform various tasks
- Increases capabilities with combined offering
- Limits data loss and downtime to a greater extent.
- Management products include • Azure Arc • Google Anthos • AWS Outposts

Pros and cons of cloud computing

Advantages of cloud computing

- **Economical**: Less infrastructure cost, less cost of ownership, fewer capital expenses
- **Operational**: cost efficient, elastic, quick provisioning, automatic updates, backup and recovery...
- **Staffing**: Less staff is required, less personal training
- **Security**: Patch application and updates, less cost on security configurations, better disaster recovery, audit and monitoring on providers side, better management of security systems.
- **Innovation**: Quick access to innovation

Disadvantages of cloud computing

- Organizations have limited control and flexibility
- Prone to outages and other technical issues
- Security, privacy, and compliance issues
- Contracts and lock-ins
- Depends on network connections
- Can be hard to migrate from one to another

Cloud regulations

- **FedRAMP**: US regulatory effort regarding cloud computing
- **PCI DSS**: Deals with debit and credit cards, but also has a cloud SIG

NIST Cloud Computing Reference Architecture

- High-level conceptual reference architecture
- Full document

Cloud actors

- **Cloud Consumer**
  - User of the cloud products and services
- **Cloud Provider**
  - Delivers cloud computing based products and services
- **Cloud Auditor**
  - Can conduct independent assessment of cloud services
- **Cloud Broker**
  - Manages the use, performance and delivery of cloud services
  - Negotiates relationships between providers and consumers
  - Service categories

    - **Service Intermediation**: Improves value of a cloud service/function
    - **Service Aggregation**: Combining multiple services to a new one
    - **Service Arbitrage**: Like aggregation but services can be chosen from different vendors.
- **Cloud Carrier**
  - Provides connectivity and transport of cloud services from providers to consumers.

Service Level Agreement (SLA)

- Span across the cloud and are offered by service providers
- Service-level agreement (SLA) is a commitment between a service provider and a client

Cloud security

- Cloud providers implement
  - Limited access and access policies
  - Access logs
  - Ability to require access reason against repudiation

Trusted Computing (TC)

- Attempts to resolve computer security problems through hardware enhancements
- **Roots of Trust (RoT)**: set of functions within TCM that are always trusted by the OS

Cloud computing risks and threats

- **Stealing information from other cloud users**
  - Internal threats where employees copying company data with bad intentions e.g. to trade.
  - Most of those breaches are not published & advertised to media.
  - Information might include e.g. credit numbers, social security numbers
- **Data loss**
  - Deleting data stored on the cloud through viruses and malware
  - ❗ High impact if there are no back-ups
- **Attack on sensitive information**
  - Stealing information about other users e.g. financial data.
- Attacker utilization of cloud infrastructure e.g.
  - **Using compute power** to crack passwords with many password attempts per seconds
  - **DDoS** attacks using cloud computing
- **Shadow IT**
  - IT systems or solutions that are developed to handle an issue but aren't taken through proper approval chain
- **Abusing cloud services**
- **Insecure interfaces and APIs**
  - E.g. weak authentication
- **Insufficient due diligence**
  - Moving an application without knowing the security differences
- **Shared technology issues**
  - Multi-tenant environments that don't provide proper isolation
  - If the hypervisor is compromised, all hosts on that hypervisor are as well
- **Unknown risk profile**
  - Subscribers don't know what security provisions are made behind the scenes.
- **Inadequate infrastructure design and planning**
- **Conflicts between client hardening procedures and cloud environment**
- **Malicious insiders**
- **Illegal access to the cloud**

    - E.g. in US data breach in 2020 a compromised global administrator account has assigned credentials to cloud service principals that allowed malicious access to cloud systems [1]
- **Virtualization level attacks**
- **Privilege escalation via error**
- **Service termination and failure**
- **Hardware failure**
    - 💡 Can be mitigated by using more zones in cloud.
- **Natural disasters**
    - 💡 Can be mitigated by using more regions in cloud.
- **Weak authentication**
    - E.g. burden of managing identity both on-premises and on cloud
        - Allows compromise on on-premises systems to spread to cloud.
        - Allows adding a malicious certificate trust relationship in cloud for forging SAML tokens on-premises.
- **Compliance risks**
    - E.g. laws regarding data transfer across borders
- **Cloud cryptojacking**
    - 📝 Hijacking cloud resources to mine for cryptocurrency
    - Often targeted on IaaS platforms through malware

Cloud computing attacks

- **Social engineering attacks** e.g. password guessing
- **Cross Site Scripting (XSS)**
- **DNS attacks** e.g. DNS poisoning, domain hijacking
- **SQL injection** to to gain unauthorized access to a database.
- **Network sniffing** e.g. obtain credentials, cookies
- **Session hijacking** e.g. cookie stealing
- **Cryptanalysis attacks** e.g. weak encryption
- **DoS (Denial-of-service)**
- E.g. In 2020 United States federal government data breach [1]

Wrapping attack

- Also known as **XML rewriting** attack
- Changes the content of the signed part without invalidating the signature.
- Intercepting a SOAP message and sending/replaying envelope with changed data.

Session riding

- Happens when an attacker steals a user's cookie to use the application in the name of the user
- Simply CSRF in cloud

Side channel attacks

- Also known as • **cross-guest virtual machine breach** • **cross-guest VM breach**
- Attacker controls a VM on same physical host (by compromising one or placing own)
- Attacker can then take advantage of shared resources (processor cache, keys, ...)
- Can be installed by a malicious insider or an impersonated legitimate user

Cloud Hopper attack

- 📝 Targets managed service providers (MSPs) and their users
- 📝 Initiated by delivering malware through [spear-phishing](#) emails
- Goal is to compromise the accounts of staff or cloud service firms to obtain confidential information
- Flow [2]
  1. Infiltrate the service provider
  2. Once inside, find system administrator who controls the company jump servers with connection to client networks
  3. Map victim network and identify sensitive data
  4. Encrypt and exfiltrate the data either through victim or the service provider
- 🤗 Named after attacks by Chinese cyber spies [2] to MSPs in countries such as UK, USA and Sweden [1]

Cloudborne attack

- Done by exploiting a specific BMC vulnerability
- 📝 Bare-metal / firmware level attack
  - Allows injecting code/backdoors
  - Affects IaaS providers that gives bare-metal access without access to the actual firmware
    - Impacting businesses that use bare metal cloud offerings
  - Survives client switches (customer customer re-assignments) performed by the provider
  - Targets baseboard management controller (BMC) firmware
    - BMC enables remote management of a server for initial provisioning, OS reinstall and troubleshooting [1] [2]
- Mitigated by IBM through factory firmware reset before re-provisioning hardware to other customers [2]
- Allows attacks such as
  - permanent denial-of-service (PDoS) on bare metal server
  - stealing data from application running on the server
  - ransomware attacks
- Revealed by Eclypsium (Firmware protection firm) in 2019 based on IBM SoftLayer cloud services [1]

Man-In-The-Cloud (MITC) attack

- 📝 Done by using file synchronization services (e.g. Google Drive and Dropbox) as infrastructure
  - E.g. as command and control (C&C), data exfiltration, and remote access.
- Makes it hard to

  - distinguish malicious traffic from normal traffic
  - discover and analyze evidence due to not leaving footprint on endpoint devices
- E.g. Switcher malware [1]
  1. Installs attackers token and moves victim's real token into *sync folder* folder to be synced
  2. Victim device is synced to attackers attacker account
  3. Attacker uses original account token and erase malicious one
  4. Removes traces of the security breach

Cloud security tools

- CloudInspect
  - Penetration-testing as a service from Amazon Web Services for EC2 users
- CloudPassage Halo
  - Automates cloud computing security and compliance controls
- privacy.sexy
  - Open-source solution to increase privacy by reducing third party cloud-based data collection
  - Can also be used to harden virtual machine images and OSes that are talking to cloud services

Containers

- More than one container can run on the same host OS.
- Docker is the standard way of running containers

Containers vs VMs

- Both reduces cost due to shared hardware.
  - A single physical server can host multiple, concurrent VMs or applications
- A virtual machine virtualizes an operating system
  - A container sandboxes an applications

Container threats

Container threat model

- **Container escape (system)**
  1. Attacker needs to escape application and end up in container with shell access
  2. Attacker than uses host or kernel exploit to escape container
- **Other containers via network**
  1. Attacker needs to escape application and end up in container with shell access
  2. Attacker attacks other containers on network
- **Attacking the orchestration tool via network**
  1. Attacker needs to escape application and end up in container with shell access
  2. Attacker attacks on management interfaces or other attacks surfaces of the orchestration tool
     - 🤗 In 2018 almost every tool has had a weakness here which was a default open management interface
- **Attacking the host via network**
  1. Attacker needs to escape application and end up in container with shell access
  2. With shell access attacker opens a port from the host
- **Attacking other resources via network**
  1. Attacker needs to escape application and end up in container with shell access
  2. Attacks e.g. on shared network-based file system, LDAP/Active Directory, Jenkins..
     - Can also install sniffer to read traffic of other containers
- **Resource starvation**
  - Attacker causes a container eating up resources which could be CPU cycles, RAM, network or disk-I/O.
  - 📝 Can cause problems affecting all other containers on same host
- **Host compromise**
  - Either through another container or through the network.
- **Integrity of images**
  - Each step in CD pipeline where container image is attack vector for the attacker.
  - Attacker can inject malicious payloads to deploy.
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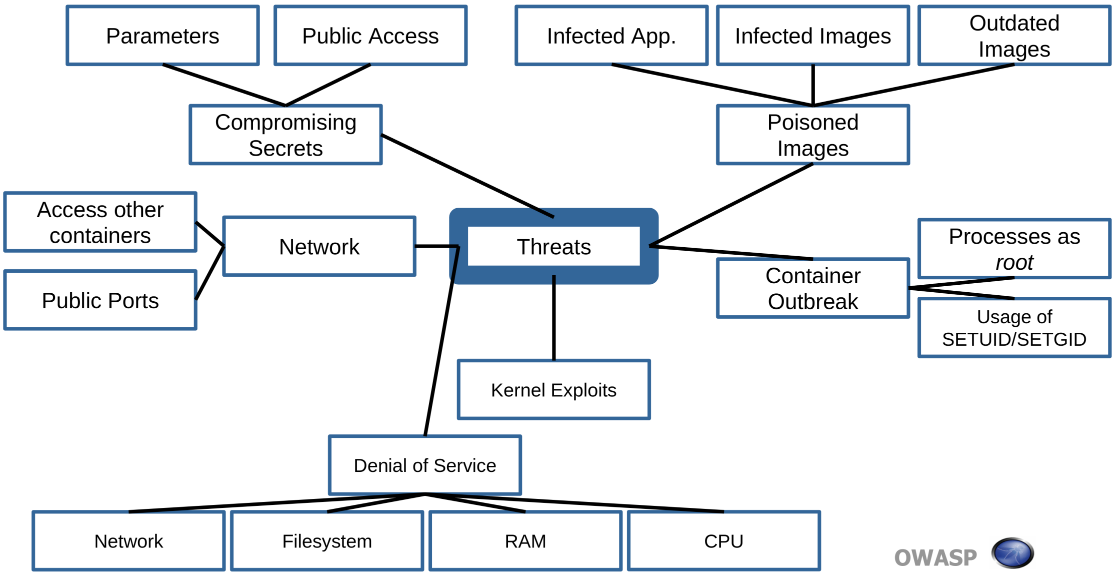

OWASP Docker Top 10

1. **Secure user mapping**
    - Docker runs with root.
    - Escape from application => root in container
2. **Patch management strategy**
    - Bugs on container/orchestration tools or OS images needs to be patched.
3. **Network segmentation and firewalling**
    - Design your network upfront providing network level protection for
        - management interfaces from the orchestration too
        - network services from the host
    - Expose microservices to only legitimate consumers
4. **Secure defaults and hardening**
    - Ensure no unneeded components are installed or started.
    - Ensure needed components are properly configured and locked down.
5. **Maintain security contexts**
    - Do not mix production containers on one host with other stages of less secure containers.
    - Do not mix frontend with backend services on one host.
6. **Protect secrets**
    - Ensure passwords, tokens, private keys or certificates are protected.
7. **Resource protection**
    - Protect shared resources such as CPU, disks, memory and networks.
    - Ensures one containers usage does not affect others.
8. **Container image integrity and origin**
    - Ensure OS in container is trustworthy until deployment.
    - Ensure images are not tampered with during transfers.
9. **Follow immutable paradigm**
    - Start containers on read-only mode if no file access is needed
10. **Logging**
    - Log on application, container image and orchestration tool
    - Both related events and API level
    - Ensure logs are stored on remote with timestamps and are tamper proof

Container attacks

- Attacks are generally not on the containers themselves, but on the applications running in them.
- Exploiting vulnerable images
  - Container image may have outdated software that has vulnerabilities if it's no longer maintained.
  - E.g. Apache OpenWhisk image (Open Source Serverless Cloud Platform) had a vulnerability where one could replace serverless functions.
- Exploiting bugs and vulnerabilities on unpatched Docker
  - E.g. a bug caused compromised images to access the host OS that has been fixed.
  - E.g. Windows Host Compute Service Shim library had remote code execution vulnerability
  - E.g. a bug allowed root privilige escalation using `docker` command
- Creating malicious container on compromised host system
  - E.g. crypto-miner containers that were running near Russian nuclear warzone
- Exploiting orchestration tool
  - Can be e.g. Kubernetes, OpenShift, Cloud Foundry or other (cloud) layer running containers.
  - See Kubernetes vulnerabilities on CVE

Container advantages over VM

- **Often no SSH enabled into containers**
  - No SSH attacks
- **Often no user access expected**
  - No need for credentials or tools to support users
- **Restricted ports by default**
  - Specific and limiting about which ports to connect
- **Short-lived containers are unlikely bases for attackers**
  - Harder to compromise a service that only lives for a few seconds/minutes.
- **Immutable designs make it difficult to inject malware**
  - As persistance is usually separated away from the container
- **Automatic generation makes it faster to pick up and promote security patches**
  - Automated CI/CD pipelines make updating libraries/OS much quicker than manual
- **Well-defined APIs enables easier anomaly detection**
  - Developers often create APIs to communicate with containers
  - Makes it easy to create a reference model for what is normal inside an application, so anything outside of that is an anomaly. We can automatically detect any anomalies

Container security countermeasures

- OWASP Docker Security Cheat Sheet
  - Keep Host and Docker up to date
  - Do not expose the Docker daemon socket (even to the containers)
  - Set a user
  - Limit capabilities (Grant only specific capabilities, needed by a container)¶
  - Add –no-new-privileges flag

    - Disable inter-container communication (--icc=false)
    - Use Linux Security Module (seccomp, AppArmor, or SELinux)
    - Limit resources (memory, CPU, file descriptors, processes, restarts)
    - Set filesystem and volumes to read-only
    - Use static analysis tools
    - Lint the Dockerfile at build time
- **Pre-deploy sources and dependency validation**
    - Ensures containers are using valid and expected code paths.
- **Pre-deploy authenticity validation**
    - Ensures that the code has not been tampered with.
- **Pre-deploy image scanning for vulnerabilities**
    - Looking for signatures of compromised packages
- **Active vulnerability scans of running containers**
    - Running automated scans after the container is deployed.
- **Network routing that includes traffic inspection**
    - Create a function based service firewall.
- **Integrated log capture**
    - Since there's no local storage, most container patterns are including central log capture and analysis
- **External injection of trust and credentials**
    - Giving credentials just-in-time to running live instances rather than static code
- **Always check running containers**
    - To ensure there's no malicious container running.
- **Ensure container images are up-to-date**
    - Unupdated/stale images might be vulnerable
- **Never-ever as root**
    - Run in rootless mode (as non root)