Storage

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Storage Options

- Amazon EC2 Instance Store
- Amazon Elastic Block Store (EBS)
- Amazon Elastic File System (EFS)
- Amazon Simple Storage Service (S3)
- Figure: Storage

Storage Units

- In the context of computer memory,
  - 1 KB = 1,024 Bytes (2^10)
  - 1 MB = 1,024 KB
- In the context of SSD/HDD
  - 1 KB = 1,000 Byte (10^3)
  - 1 MB = 1,000 KB
- Amazon uses KiB (Kibibyte), MiB (Mebibyte), GiB (Gibibyte) Standard units – Matches with memory
  - 1 KiB = 1,024 Bytes
  - 1 MiB = 1,024 KiB

Storage Option Comparison

Description	Instance	EBS	EFS	S3
Latency	Lowest	Lowest	Low	Higher
Throughput	High	Single GB/s	Multiple GB/s	Managed
Concurrent	Only 1	1 at a time	Many 1000s Linux instances	Many 1000s
Scope	Instance	Availability Zone	VPC	Anywhere
Storage Device	SSD, HDD	SSD, HDD	Managed	Managed
Redundancy	Instance level	Availability Zone	Multi-Availability Zone	Multi-Availability Zone
I/O Semantics	File I/O	File I/O	File I/O	Object
Usage	Boot, Data, Database	Boot, Data, Database	Data, Home directory	Data

EBS, EFS, Instance Pricing – Example of US West (Oregon)

Volume Type	Price per GB-month	Price per Provisioned IOPS
EBS General Purpose SSD (gp2)	$0.10	
EBS Provisioned IOPS SSD (io1)	$0.125	$0.065
EBS Throughput Optimized HDD (st1)	$0.045	
EBS Cold HDD (sc1)	$0.025	
EBS volume Snapshots	$0.05	
EFS	$0.30	
Instance Store	Included with instance pricing	

Prices are prorated to the hour if data stored for less than a month

EC2 Instance Store

- Instance store is dedicated for an instance but the disk subsystem is shared with other instances on the host
- Instance Store volumes can be added only during launch
- Pricing – Instance store is included as part of instance's hourly cost
- Supported only on specific Instance Types

Amazon EC2 Instance Store

- Instance Store is storage from disks physically attached to host computer
- Temporary block storage for instances
- Data persists across reboots
- Data is lost when instance is stopped, terminated, or host system has a hardware failure
- Ideal for frequently changing data such as buffer, cache, scratch data or for data that is replicated across multiple instances

Amazon Elastic File System (EFS)

- EFS provides a scalable file storage for EC2
- Mount on multiple instances
- Use as a common data source for workloads or applications running on multiple instances
- Concurrent access from different instances
- Grows and Shrinks automatically
- Automatic replication across multiple AZs in a region
- Low latency access
- Not supported on Windows instances

Amazon Simple Storage Service (S3)

- Object storage service for the internet
- Reliable and inexpensive
- Store and retrieve any amount of data
- Accessible anywhere on the web
- Automatic replication across multiple Availability Zones in a region
- Lifecycle policies to manage data
- EC2 uses S3 to store EBS snapshots and instance-store backed AMIs

EBS Pricing Example – Hourly Example

- 500 GB stored for 15 hours
- 30 days month
- No. of hours = 30 * 24 = 720
- Convert price to hourly pricing

Storage Cost: price * size * 15 / 720

Provisioned IOPS Cost: price * IOPS * 15 / 720

Total: Storage Cost + Provisioned IOPS Cost

EBS Pricing Example – Month Example

- 500 GB stored

Storage Cost: price * size

Provisioned IOPS Cost: price * IOPS

Total: Storage Cost + Provisioned IOPS Cost

Hourly Pricing Example - US West (Oregon)

- Example Spreadsheet for hourly calculation
- AWS Simple Monthly Calculator
- Impact of provisioning IOPS on cost

Amazon Elastic Block Store (EBS)

- EBS provides durable block level storage volumes with optional encryption
- EBS volume behave like a raw, unformatted, external block device
- Attach to a single instance (even running instances)
- Volume persists independently of instance
- Attach multiple volumes to one instance
- Detach from one and attach to another
- Automatic replication across one Availability Zone

EBS

- Pay only for what you use
- Consistent low latency performance
- Suitable as a primary storage device that requires frequent and granular updates: file systems, databases or any application that needs raw, block level storage.
- Integrated backup mechanism known as *snapshot*
- Snapshot is stored in S3 with region level replication
- Create a new EBS volume from a snapshot and attach to another instance

EBS Encryption

- Launch EBS volumes as encrypted volumes in supported instance types (only more powerful ones)
- Integrated with Amazon Key Management Service (KMS) - Simple encryption solution without the need for you to build, manage and secure your own key management infrastructure
- Encryption is performed on server that host instances
    - Data stored at rest is encrypted
    - Disk I/O – Data in transit is encrypted
    - Snapshots from the encrypted volume are also encrypted

EBS Encryption

- Encryption Algorithm
  - 256 bit AES
  - Use default master key automatically created for you in KMS
  - Create your own Customer Master Key (CMK) in KMS
- CMK is more flexible:
  - Granular access control
  - Rotate keys periodically
  - Disable keys
  - Audit usage of encryption keys

EBS Volume Types

- General Purpose SSD (gp2)
- Provisioned IOPS SSD (io1)
- Throughput Optimized HDD (st1)
- Cold HDD (sc1)

Table: Volume Type Comparison

Max Volume Size: 16 TiB

General Purpose SSD (gp2)

- Baseline performance 3 IOPS / GiB
- Designed for I/O intensive workload
- Ability to burst up to 3,000 IOPS for short period – uses I/O credits
- Max 10,000 IOPS (for volume size 3,334 GiB)
- Max 160 MiB/s throughput
- Ideal for boot volumes, small-medium databases, development and test environments

Provisioned IOPS SSD (io1)

- Provision specific level of I/O performance
- Designed for I/O intensive workload
- Max 20,000 IOPS
- Max 320 MiB/s throughput
- Consistent and predictable performance
- Ideal for mission critical usage and databases
- Delivers within 10% of provisioned IOPS 99.9% time of the year
- Max 50 IOPS / GiB

Throughput vs IOPS

Provisioned IOPS and Throughput

Throughput Optimized HDD (st1)

- Low cost magnetic storage
- Optimized for large, sequential I/O to maximize throughput
- Max 500 MiB/s throughput
- Ideal for large, sequential workload like MapReduce, ETL, data warehouses, log processing
- Cannot be used as a boot volume

Cold HDD (sc1)

- Low cost magnetic storage
- Optimized for large, sequential I/O to maximize throughput
- Max 250 MiB/s throughput
- Ideal for infrequently accessed large, sequential, cold data workloads
- Save storage costs
- Cannot be used as a boot volume

EBS Optimized Instances

- EC2 instance types that are EBS optimized use an optimized configuration stack
- Provides additional, dedicated capacity for EBS I/O
- Storage for High Performance
- Minimizes contention between EBS I/O and other traffic from the instance
- Throughput ranges from 500 Mbps to 10,000 Mbps based on instance types

EBS Optimized Instances

- General Purpose SSD (gp2) – Designed to deliver within 10% of baseline and burst performance 99% of time in a year
- Provisioned IOPS SSD (io1) - Designed to deliver within 10% of provisioned performance 99.9% of time in a year
- Throughput Optimized HDD (st1) and Cold HDD (sc1)
    - Guarantee Performance consistency 90% of burst throughput 99% of time in a year
- Non-compliant periods are distributed uniformly in a year

Snapshot

- Point-in-time snapshot of EBS volumes
- Stored in S3
- Can be used as a starting point for new EBS volumes and change volume size
- Copy across regions
- Incremental snapshot capacity – stores only delta blocks for subsequent backup. Ideal for periodic snapshot
- Share with other accounts or make it public

EBS Availability Zone

- EBS volumes are created in specific Availability Zone
- Can be attached to any instance in that same AZ
- To use across different AZ in the same region
    - Create a snapshot
    - Restore snapshot to a new volume in a different AZ
- To use across different regions
    - Create a snapshot
    - Copy snapshot to S3 in another region
    - Restore snapshot to a new volume in that region

Snapshot Volume Restore

- New volumes created from snapshot are restored *lazily in the background*
- Volume can be immediately attached and used in an instance
- If instance accesses block that is not available, it is immediately downloaded from S3 – can increase latency
- To minimize latency of restores, force download all blocks using dd or fio commands in linux

Snapshot and Encryption

- Snapshots of encrypted volumes are automatically encrypted
- Volumes created from encrypted snapshot are automatically encrypted
- Snapshot Copy process allows you to encrypt an unencrypted snapshot during copy operation
- Snapshot Copy process allows you to reencrypt a snapshot with a different encryption key when copying an encrypted snapshot.

Snapshot Creation Process

- Initial snapshot creation can take a long time – full backup
- Subsequent snapshot on the volume are incremental – captures the changed blocks
- You can retain most recent snapshot and delete all older snapshots – designed to restore fully
- Snapshot is created immediately – but in pending state until it completes
- System can read/write to volume when snapshot is in progress

Snapshot Creation Process

- Volume in-use – snapshot is point-in-time; however, it may exclude data cached in application or OS.
- To ensure application consistent snapshot, pause the application or write and issue snapshot
- If that is not possible, unmount volume, issue snapshot, remount the volume
- For transactional databases, perform backup through database management software and store the backup in S3
- For root device snapshot, stop the instance before issuing snapshot command

Snapshot Copy

- Geographic expansion – Launch in a new region
- Migration – Move an application to a new region
- Disaster Recovery
- Encryption
    - Encrypt a previously unencrypted snapshot
    - Change the encryption key
    - For Shared snapshots, create your own copy in order to restore to a volume – you need permissions to use customer master key of the source account that was used to encrypt
- Audit and Date Retention - Copy to a different account

Sharing Your Snapshot

- Snapshots are constrained to a region
  - Copy to other regions if needed
- Unencrypted Snapshot
  - Private Sharing - Share with other AWS accounts
  - Public Sharing – accessible to everyone
- Encrypted Snapshot
  - Public Sharing – Not allowed
  - Private Sharing – Encryption key should not be default. Customer Managed Key (CMK) should be used. Accounts you are sharing with has access to this CMK

Expanding EBS Volume

- EBS volume size and volume type can be changed without losing data
- Stop the instance
- Take a snapshot of the volume
- Create a new volume with the snapshot. Specify desired volume type and size
- Detach the old volume from the instance
- Attach the new volume to the instance with the same device mapping

EBS Monitoring

- Accessed through CloudWatch
- Key metrics: throughput, IOPS, bandwidth, latency, average queue length and so forth
- Automated status checks every 5 mins – detect impaired or not enough space
- No additional charge

Table: EBS Metrics and Status Checks

EBS Volume Performance Tips

- Use EBS optimized instances or 10 Gb network connectivity for performance sensitive workload
- Understand your workload
  - Random I/O or Sequential I/O
  - IOPS
  - I/O Size
  - Throughput = IOPS x I/O Size
- Pick an Instance type with enough bandwidth
- Enable 10Gb Network - especially when there are multiple RAID 0 EBS volumes (striped)

EBS Volume Performance Tips

- Monitor CloudWatch metrics and Volume Status
- Initialize volumes restored from snapshot – lazy loading can cause inconsistent performance. Initialize by reading all blocks to ensure consistent performance (dd or fio on linux)
- Use RAID 0 (non-boot volumes) – to support performance needs beyond what a single volume could provide

EBS Volume Performance Tips

- HDD instances degradation
  - Throughput hit when snapshot is running
  - Excessive amount of small random I/O on HDD
- Not enough requests sent by application
- Use modern kernel
- Benchmark EBS volumes – by type and provisioned capacity

Instance Volume Limits

- Maximum number of volumes that can be attached to instance varies by Operating System
- Assess if you need more storage capacity or need more I/O bandwidth
- Linux – Attaching more than 40 volumes can be cause boot failures
- Windows – Varies by PV driver. Maximum 26 volumes

Service Limits

- AWS sets resource limits on a per-region basis
- Some limits are soft limits and you can contact support to increase the limit.
- For example
    - Total number of EC2 instances running are limited to 20
    - EBS maximum aggregate provisioned IOPS 40,000
    - EBS Volume Type Maximum storage 20 TiB
    - EC2 Elastic IPs 5 per region
    - VPCs 5 per region (excluding default)

Public Data sets

- Amazon makes available large public data sets for free
  - Human Genome project, Census Data, Labor statistic, Wikipedia content and so forth
  - Readily use this data with AWS services
- Provide researchers with tools to enable innovation
- Data sets are available in two formats:
  - EBS snapshots -> Create new volume and attach to instance
  - S3 buckets -> Copy data to your instance

Tagging Resource

- Tags allow you to put you own metadata to an instance. It is a key-value pair.
- Manage AWS resources (for EC2 instance purpose, or Volume purpose)
- Organize Billing using tags – signup to get your account bill with tag values included

Usage Report

- Billing report
- Instance usage report
- Reserved instance utilization report
- Access AWS management console - Instructions

Adding Storage to Instance

- Every time an instance is launched from AMI, root storage device is created for that instance
- Root storage device contains all the information to boot the instance
- Additional storage volumes can be specified when AMI is created or instance is launched
- Attach additional EBS volumes to a running instance