Advanced Data Analytics in Cyber Security (P'grad)

Study Tour & Internship in Chennai India

- **T3:** November/December 2019
- **Credit:** 2 Deakin credit points (1 for Study Tour, 1 for Internship)

Information Session:
When: 1pm - 2pm, Monday, 20 May 2019, T3.22 – join us!

Who is eligible?
Study Tour – must have elective space (no tuition fee)
Internship – must have space to do internship unit

Funding available:

- $2000 Faculty Internship grants for international students

Cost:

- Program fee: AU$4000 (includes Study Tour, Internship, airport pick up & accommodation)
- Does not include: Flights, visa's and meals.

Interested? Contact sebe-international@deakin.edu.au

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SIT706
Cloud Computing Technologies

Week 9

Storage – Deep Dive

Week 9 Outline

- Storage – Deep Dive
  - Background
  - Basic Concepts
  - Storage in Clouds
  - Future Developments

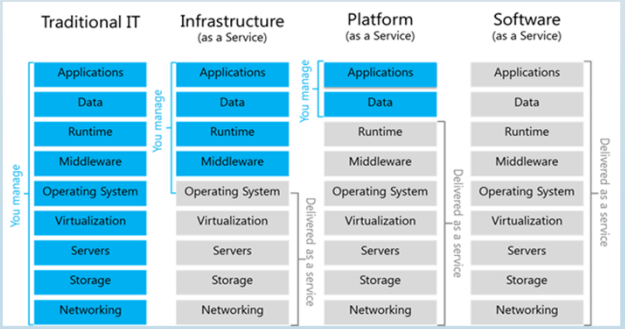
Background

Background

1. Cloud Deployment Models
2. Hierarchy
3. Capacity
4. Disk Arrays

Background: Cloud Delivery Models

- **Storage is an important component** of computing systems, and **in all forms** of the cloud delivery



Background: Hierarchy

- Storage is composed of **many different devices**:
  - Primary
  - Secondary
  - tertiary
- Each form has **different characteristics**:
  - Capabilities
  - Capacities
  - Price
  - Problems

Background: Hierarchy

Primary Storage

- Primary storage is also known as internal memory or main memory and is the only storage that is accessible to the CPU directly.
- It is basically the memory storage part of the computer system.
- Primary storage is inclusive of the Random Access Memory (RAM) and the Read Only Memory (ROM).

Background: Hierarchy

Secondary Storage

- Secondary storage is also known as external memory.
- This storage type differs from the primary storage in a way that it is not accessible by the CPU directly.
- Magnetic tapes, hard disks and all other external storage devices make a part of the secondary storage.
- This storage type is external to the processor and is usually used to supplement the storage capacity of the computer.

Background: Hierarchy

Secondary Storage (cont.)

- The secondary storage can retain information or memory even after the computer is turned off and hence is non-volatile.
- Some of the most commonly used secondary storage devices include the following:
  a. Hard dices
  b. DVD
  c. Blu-ray Discs
  d. Compact Discs etc.

Background: Hierarchy

Tertiary Storage

- Tertiary storage, also referred to tertiary memory, offers a third level of data storage.
- This storage type is inclusive of devices that are connected to the computer as removable mass data storage devices.
- Tertiary storage devices are commonly used for the storage of files that are rarely accessed by the user.

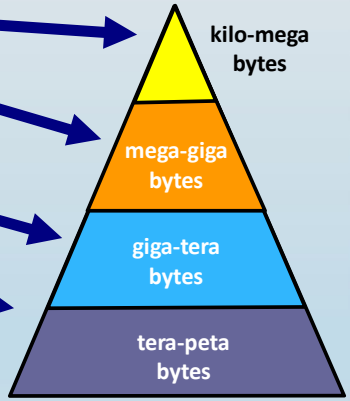
Background: Hierarchy

Tertiary Storage (cont.)

- The main benefit of the tertiary level of data storage is to provide enormous capacity for storage at low costs.
- These storage devices include fixed storage drives and removable media units.
- The fixed storage drives is fixed to the computer system and the latter can be removed from the drives in order to expand the data storage capacity with more media units.

Background: Hierarchy

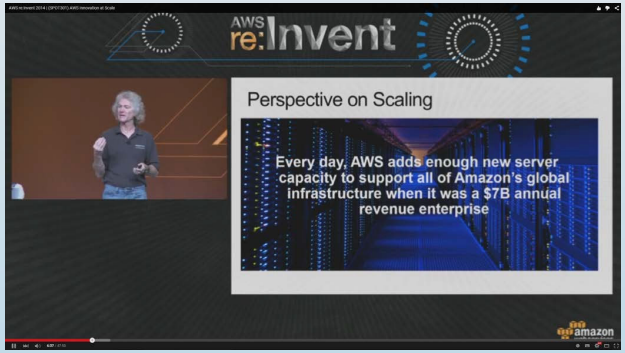
- Primary Storage: CPU
  - Registers (1cycle, a few ns)
  - Cache (10-200+ cycles, 0.02-0.5us)
  - Local main memory (0.2-4us)
  - NUMA memory (2-10x local memory)
- Secondary Storage (online storage)
  - Magnetic disks (2-20ms)
  - Solid state disks (0.05-0.5ms)
  - Cache in storage controller (as SSD)
- Tertiary Storage
  - Removable media: tape, cartridges, BD/DVD, … (ms to minutes)
  - Tape libraries, optical juke boxes (nearline) (fews to few minutes)
  - Tape vaults (few minutes to days)



Background: Capacity

- Difficult to find actual data on the **total capacity of cloud providers**, but arguably in the Exabyte range.
- Google has ~ 10 Exabytes (Randall Munroe 2014)
  - Exabyte = 1000 Petabytes
  - Petabyte = 1000 Terabytes
  - Exabyte = 1,000,000,000,000,000,000 bytes

Background: Capacity



Example: Amazon increases server/storage capacity Every day! (AWS Re:Invent 2014) https://youtu.be/JIQETrFC_SQ

Background: Capacity

- There is list of, the most recent and popularly used method is cloud storage.
- This is an enterprise-level data storage type and is used by business organizations for the storage of valuable business data.

Background: Capacity

Provider Name	Storage	Price
Just Cloud.com	Unlimited	$4.49/month
myPC Backup.com	Unlimited	$4.49/month
Zip Cloud	Unlimited	$4.49/month
BackupGenie	Unlimited	$4.49/month
LiveDrive	Unlimited	$7.95/month
SugarSync	60 GB	$4.99/month
Dropbox	50 GB	$9.99/month
Mozy	125 GB	$7.99/month
Carbonite	50 GB	$4.91/month
SOS	50 GB	$5.33/month

Source: http://www.cloudstoragebest.com/data-storage-types/

Background: Disk Arrays

- Clusters of **Disk Arrays** are used by large cloud providers
- A disk array consists of:
  - Multiple **disks**
  - Extra **controlling** mechanisms
  - **Cache**, etc.
- A disk array is used because:
  - Single disks are **slow**
  - **Faults/errors** can (will) happen

Background: Disk Arrays

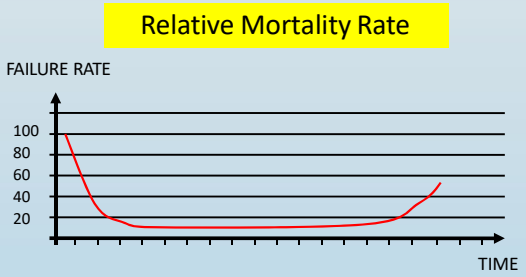
QNAP TS-831X 8 Bay NAS, 8GB

Background: Disk Arrays

QNAP TS-831X 8 Bay NAS, 8GB

Background: Disk Arrays

- Failures happen, things break in a moderately predictable way



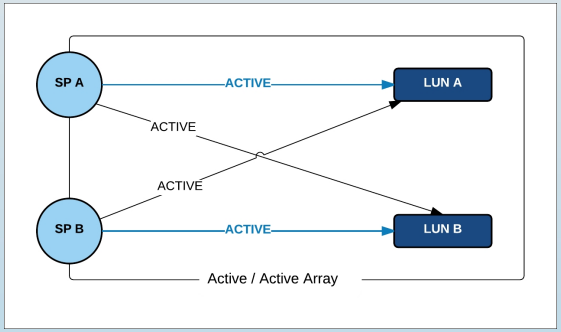
Disk Arrays Types

- There are three types of arrays based on their load balancing or failover abilities:
  a. Active/active array
  b. Active/passive array
  c. ALUA (Asymmetric Logical Unit Access) array

Disk Arrays Types

- **Active/active array**
  - ✓ **A**ll the ports on its storage controllers to allow simultaneous processing of the I/O offering the same levels of performance and access to all LUNs.
  - ✓ In this array there is no concept of a standby controller.

Disk Arrays Types



Disk Arrays Types

- **Active/active array**
  - Design Consideration:
    - When designing a storage architecture with a **active/active array**, There are options of choosing different preferred paths on different sets of **ESXi** hosts in a cluster/data centre.
    - **Examples:** If you have a 10 hosts cluster, then you could set five hosts to use a preferred path via controller-1 and a second set of five hosts to use a preferred path via controller-2.
    - This is done to achieve I/O processing load distribution at the controller level.

Disk Arrays Types

- **Active/passive array**:
- In an active/passive disk array, one Storage Processor(SP) is actively servicing a given Logical Unit Number(LUN) .
- The other SP acts as backup for the LUN and may be actively servicing other LUN I/O.
- I/O can be sent only to an active processor.
- If the primary storage processor fails, one of the secondary storage processors becomes active, either automatically or through administrator intervention.

Source: VMWARE on line library

Disk Arrays Types

- **Active/passive array**:

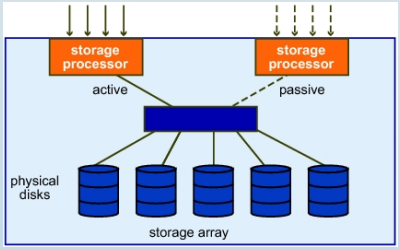


Figure: Active/passive Storage Array

Source: VMWARE on line library

Disk Arrays Types

- **ALUA (Asymmetric Logical Unit Access) array**
- It is generally knows as hybrid approach
- In this approach, both controllers are at work, but Logical Unit Numbers (LUNs) have an affinity to a specific controller and usually, if you access the LUN from a different controller, You need to pay a performance price. In addition, the performance per LUN is limited to that of a single controller
- Therefore you need to start manual load balancing of the LUNs between controllers.

Basic Concepts

Basic Concepts

1. Durability
2. Redundancy
3. Partial Redundancy
4. Redundancy: Advantages
5. Redundancy: Disadvantages
6. Disk Array Taxonomy
7. RAID Levels 5
8. Disk Array Architecture
9. Hosts, Networks and Storage
10. DAS
11. NAS
12. SAN
13. SAN Networks

Basic Concepts: Durability

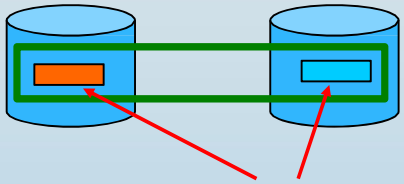
- Durability (not loosing data) is critical importance.
  - Amazon S3 is designed for 99.999999999% durability and 99.99% availability of objects over a given year (http://aws.amazon.com/s3/details/#durability)

Basic Concepts: Redundancy

- Redundancy is a solution to the fault tolerance problem of disks
- Redundancy can come in two forms:
  - Complete Redundancy (Copies)
  - Partial Redundancy

Basic Concepts: Redundancy

- Complete copies
  - Replication, aka mirroring

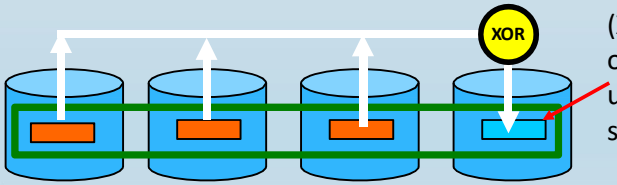


Basic Concepts: Partial Redundancy

- Error Correcting Codes (ECC)
  - Detect errors
  - Correct errors
- Hamming codes
  - Parity bits + Data bits = Total bits
  - Unnecessarily strong, we know when a disk is broken

Basic Concepts: Partial Redundancy

- Parity
  - Exclusive-Or data blocks to calculate a parity block
  - Any data block can be re-constructed from the other blocks + parity block



Parity Unit (XOR of rest of stripe units in same stripe)

Basic Concepts: Redundancy: Advantages

- Individual disks
  - Originally (mid 1980's), these were among the most unreliable components in a system
  - Nowadays, they are one of the most reliable ones (Annual Failure Rate 1 to 2%)
- **But failure rates are proportional to numbers** (imagine a cluster of disk arrays)

Basic Concepts: Redundancy: Advantages

- With no redundancy
  $AFR_{disks} \approx N_{disks} \times AFR_{disk}$
- With one degree of redundancy
  $AFR_{raid} \approx AFR_{disks}(N_{disks}) \times MTTR_{disk} \times AFR_{disks}(N_{disks}-1)$

MTTF : Mean time to failure (a rate not a period)
AFR : Annual failure rate
MTTR : Mean time to repair

Basic Concepts: Redundancy: Disadvantages

- Cost
  - Replicating everything costs 2x as much
  - Solution – partial redundancy
- Slower updates
  - 2x as many copies to write
  - Even worse with partial redundancy
- Greater complexity
  - 80-90% of disk array firmware is error handling
  - Lots and lots of configuration choices …

Basic Concepts: Disk Array Taxonomy

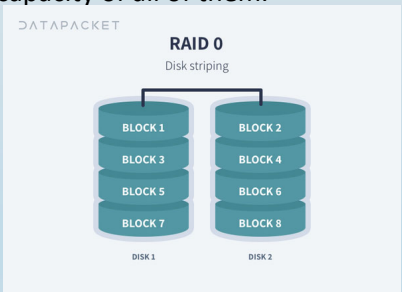
- RAID = Redundant Array of Inexpensive Disks
- Currently accepted RAID levels:
  - **0 : no redundancy striping (just a bunch of disks JBOD)** splits data across any number of disks allowing higher data throughput. ...
  - **1 : full copy (mirroring)**
  - **10 (said one-zero) : striping plus mirrors**
  - 2 : Hamming-codes / ECC (not used)
  - 3 : byte-interleaved parity
  - 4 : block interleaved parity (more useful variant of RAID3)
  - **5 : rotated block-interleaved parity**
  - 6: double parity (rare)

Basic Concepts: RAID levels

- **RAID 0 :**RAID 0 splits data across any number of disks allowing higher data throughput.
- An individual file is read from multiple disks giving it access to the speed and capacity of all of them.

Pros: Increased Performance (Write and read speeds).

Cons: No redundancy.



Source: https://datapacket.com/blog/advantages-disadvantages-various-raid-levels/

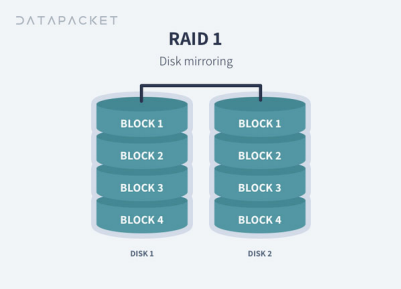
Basic Concepts: RAID levels

- RAID 1 writes and reads identical data to pairs of drives. This process is often called data mirroring and it's a primary function is to provide redundancy. If any of the disks in the array fails, the system can still access data from the remaining disk(s). Once you replace the faulty disk with a new one, the data is copied to it from the functioning disk(s) to rebuild the array. RAID 1 is the easiest way to create failover storage.

Source: https://datapacket.com/blog/advantages-disadvantages-various-raid-levels/

Basic Concepts: RAID levels

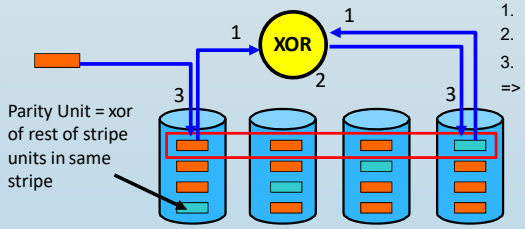
Pros: Fault tolerance and easy data recovery. Increased read performance.
Cons: Lower usable capacity. Higher cost per megabyte (double the amounts of drives is required to achieve desired capacity).



Source: https://datapacket.com/blog/advantages-disadvantages-various-raid-levels/

Basic Concepts: RAID Level 5

- RAID 5: rotated parity striping to balance the load
- Updating parity is expensive for small writes
  - Write-caching becomes especially important



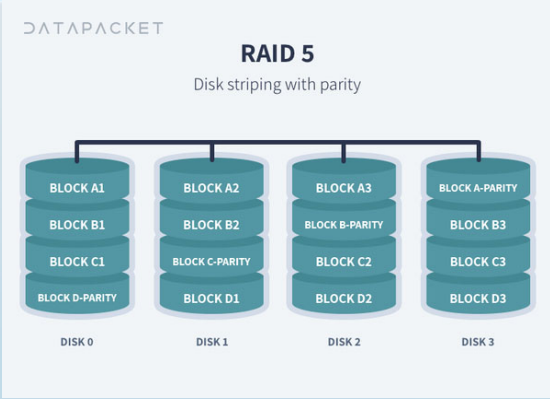
1. Read old data & parity (2 I/Os)
2. Compute new parity
3. Write new data & parity (2 I/Os)

=> 4x I/O operations per small write

Rotating Parity balances the parity load across all the disks; striping allows fast large transfers

RAID5 is the configuration of choice for all but performance-intensive workloads

Basic Concepts: RAID Level 5



Source: https://datapacket.com/blog/advantages-disadvantages-various-raid-levels/

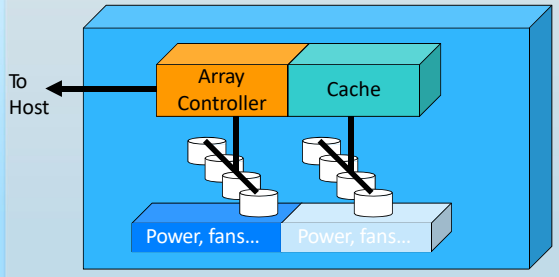
Basic Concepts: RAID Level 5

- **Minimum number of disks:** 3
- **Pros:** Fault tolerance and increased performance (lower than RAID 0)
- **Cons:** Lower performance with servers performing large amounts of write operations because of parity overhead.
- **Ideal use:** File storage servers and application servers.

Source: https://datapacket.com/blog/advantages-disadvantages-various-raid-levels/

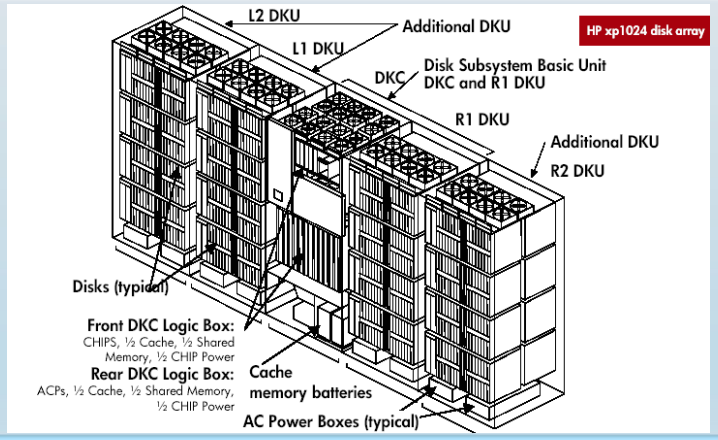
Basic Concepts: Disk Array Architecture

- May have separate boxes for controller and disks
- Many TB of disks, many GB of cache

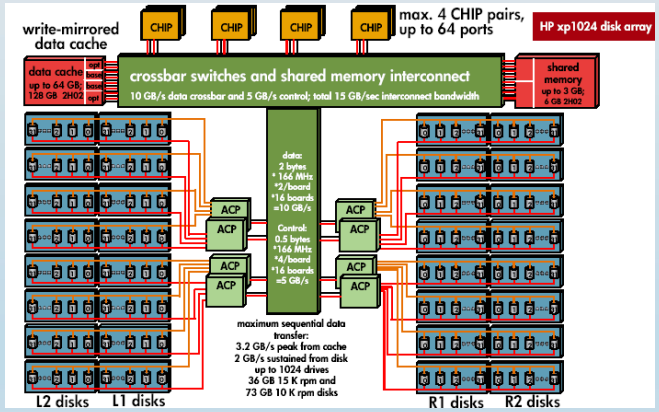


EMC 500 Disk Array

Basic Concepts: Disk Array Architecture



Basic Concepts: Disk Array Architecture



Basic Concepts: Hosts, Networks and Storage

- Till now we have only looked at the lowest level items in the storage picture
  - the disks, and
  - disk arrays
- We need to look at the complete picture, including those that use the storage

Basic Concepts: Hosts, Networks and Storage

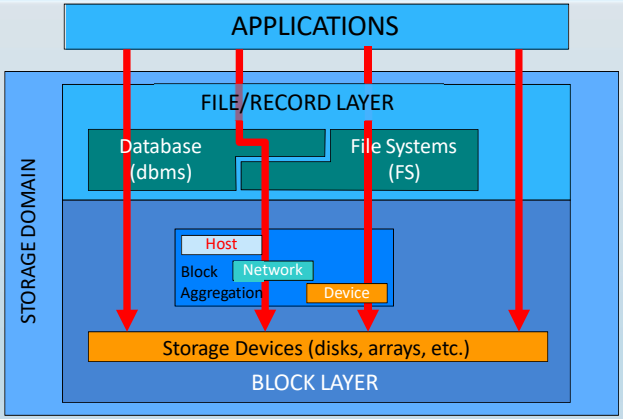


Figure from SNIA 2000-2003 (Storage Networking Industry Association)

Basic Concepts: Hosts, Networks and Storage

- What do disks/arrays present to the higher (application) layers?
  - Blocks: 512 or 1K '*chunks*' of data
  - Disks: can be '*whole*' or '*partitioned*'
  - Disk Arrays: present multiple LUNs
    - LUN = Logical Unit (of management or control)
    - One or more disks, with same configuration (RAID)
    - LUNs can have different sizes / layouts
    - 10-20 LUNs for mid range arrays…1000's for high end arrays
      - SCSI has a limit of 4096 (12 bit identifier)

Basic Concepts: Hosts, Networks and Storage

- How do hosts/servers connect to disks/arrays?
- Three common methods:
  - Direct Attached Storage → *DAS*
  - Network Attached Storage → *NAS*
  - Storage Area Networks → *SAN*

Basic Concepts: Direct Attached Storage (DAS)

- Most well know, used in your PC
- Uses common/well used protocols:
  - **IDE** (Integrated Drive Electronics) : simple general purpose bus system
  - **Small Computer System Interface (SCSI):**higher capacity bus
- Well known protocols… bus oriented…
- But DAS makes it difficult to share data

Basic Concepts: Network Attached Storage (NAS)

- Special, purpose built file server
  - Windows or Linux OS foundation
  - Provides nothing but files… no other services
- Benefits:
  - Aggregates blocks from multiple disks
  - Layout and caching can be optimised
  - Finer grained protection can be achieved
  - Enables HTTP like protocols access to files

Basic Concepts: Network Attached Storage (NAS)

- Disadvantages:
  - Performance? Another 'thing' in the way of data and application
  - Limitations on size of storage managed

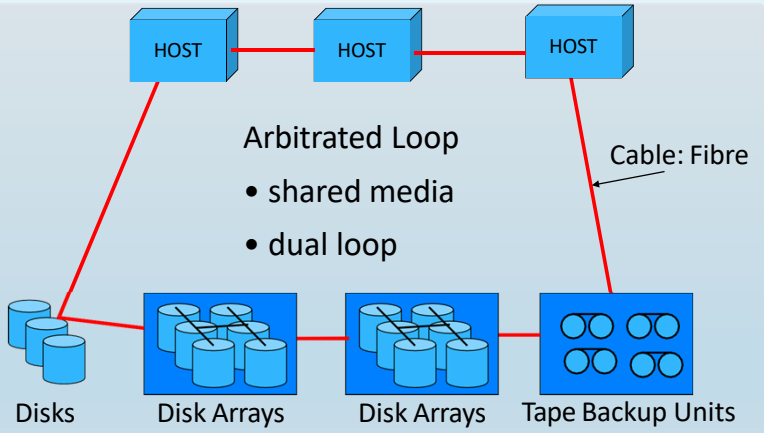
Basic Concepts: Storage Area Networks (SAN)

- Blocks are primary unit of data
- Dedicated network… used primarily for storage
- Benefits:
  - High Performance and reliability
  - Flexibility – many configurations… disks, arrays, hosts, tapes
  - No (or extremely large) limitations on amount of storage
- Disadvantages:
  - Cost… specialised networks and interfaces…

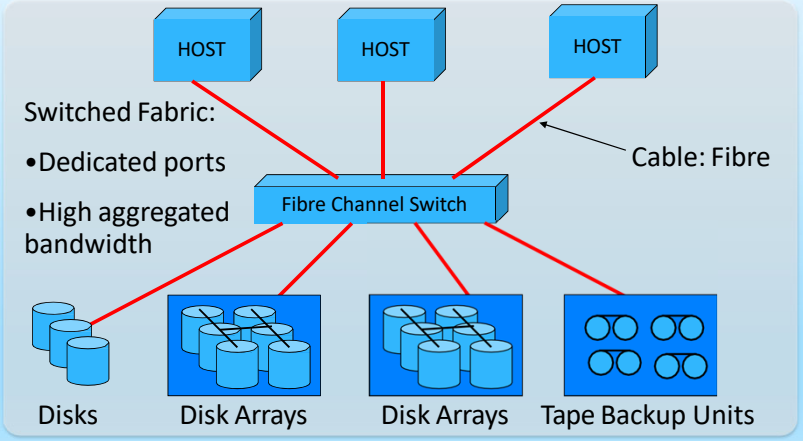
Basic Concepts: SAN Networks

- Dedicated networks, most common is Fibre Channel
  - High speed (2-16 Gbit/s)
  - Specialised protocols FCP (Fibre Channel Protocol) designed for storage (close support for SCSI)
  - Requires FC network interfaces and switches

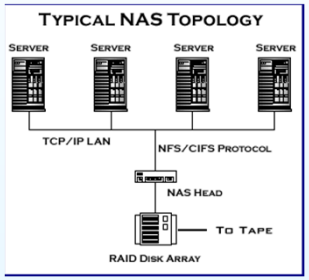
Basic Concepts: SAN Networks



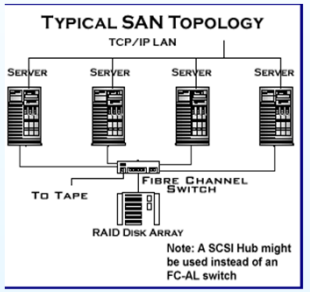
Basic Concepts: SAN Networks



NAS vs SAN



- Almost any machine that can connect to the LAN (or is interconnected to the LAN through a WAN) can use NFS, CIFS or HTTP protocol to connect to a NAS and share files.



- Only server class devices with SCSI Fibre Channel can connect to the SAN. The Fibre Channel of the SAN has a limit of around 10km at best

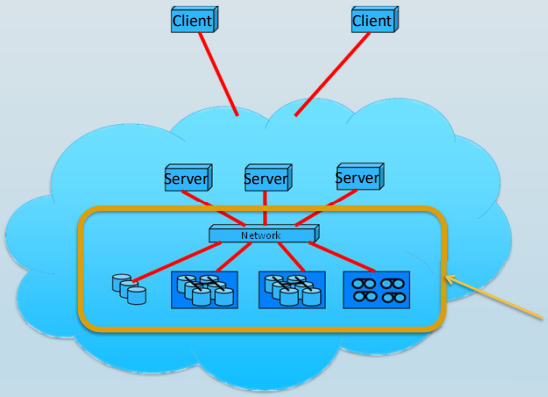
Source: http://www.nas-san.com/differ.html

Cloud Storage

Cloud Storage

1. Components
2. Devices
3. Requirements
4. Virtualisation Management

Cloud Storage: Components



Storage interconnected to servers

Cloud Storage: Devices

- Recall that cloud storage devices are:
  - Can be virtualized, similar to virtual servers
  - Commonly able to provide fixed-increment capacity allocation
  - Can be exposed for remote access via cloud storage services
  - Primary concern is the security, integrity, and confidentiality of data

Cloud Storage: Devices

- Cloud Storage Levels:
  - **Files**: collections of data grouped into files located in folders
  - **Blocks**: lowest level of storage and closest to hardware
  - **Datasets**: data organised into table-based, delimited, or record format
  - **Objects**: data and its associated metadata organised as web-based resources

Cloud Storage: Devices

- **Network Storage Interfaces**: legacy network storage including:
  - SCSI for storage blocks
  - server message block (SMB)
  - common Internet file service (CIFS)
  - Network File System (NFS)

Cloud Storage: Devices

- **Object Storage Interfaces**:
  - typically accessed via REST or web service-based cloud services
  - Storage Network Industry Association's (SNIA's) Cloud Data Management Interface (CDMI)

Cloud Storage: Devices

- **Database Storage Interfaces**:
  - typically support a query language in addition to basic storage operations
    - Relational Data: usually SQL-based, e.g., DB2, Oracle, MSSQL, MySQL
    - Non-relational Data (or NoSQL databases): uses a "looser" structure (no data relations) to avoid complexity and processing overhead

Cloud Storage: Requirements

Characteristic	Description
Manageability	The ability to manage a system with minimal resources
Access method	Protocol through which cloud storage is exposed
Performance	Performance as measured by bandwidth and latency
Multi-tenancy	Support for multiple users (or tenants)
Scalability	Ability to scale to meet higher demands or load in a graceful manner
Data availability	Measure of a system's uptime
Control	Ability to control a system—in particular, to configure for cost, performance, or other characteristics
Storage efficiency	Measure of how efficiently the raw storage is used
Cost	Measure of the cost of the storage (commonly in dollars per gigabyte)

M. Tim Jones, Anatomy of a cloud storage infrastructure, Nov 2010 ibm.com/developerWorks)

Cloud Storage: Requirements

- As with all components of the Cloud, storage is also virtualized
- This helps enable features such as:
  - Data organisation and management
  - Support for QoS and SLAs – monitoring
  - Data migration and load balancing
  - Data deduplication (improves storage efficiency)
  - Storage security

Cloud Storage: Virtualisation Management

- Recall features of VMware vSphere 6.0:
  1. Abstracts storage devices into a '**datastore**' which can then be allocated for direct VM storage, template storage, and optical media image (ISOs)
  2. **Datastores** can be implemented on block-based storage (hard disks / SSDs), direct-attached storage (DAS), Fibre Channel, Fibre Channel over Ethernet (FCoE), and iSCSI, and remotely accessed using either VMFS or NFS

Cloud Storage: Virtualisation Management

3. **Datastores** can be presented to OSs as virtual hardware using SCSI and IDE (SATA) controllers
4. Automatic selection of storage for load balancing based on latency or capacity
5. Storage selection simplified by grouping storage according to user-defined policy
6. Supports storage migration to eliminate I/O bottlenecks and free up storage capacity

Cloud Storage: Virtualisation Management

7. Prioritises access to I/O resources based on business needs (policy)
8. Supports thin provisioning to ensure VMs only use storage they need, not what is allocated (virtual disk size, etc.)
9. Use of flash-based caching, (PCIe cards or SSDs), for improved performance that can be managed per virtual disk

Future Developments

Future Developments

- Increased role of SSD (Solid State Drive) in storage composition
- Resurgence of old technologies
  - Use of (LTO) Tape for off-line back up
    - Google's *Nearline*
    - Amazon's *Glacier*

Future Developments: Example

- DreamWorks Animation recently implemented an active archive solution to safeguard a 2-petabyte portfolio of video animation assets, supporting a long-term asset preservation strategy. The studio's comprehensive, tiered converged active archive architecture—which spans software, disk and tape—saves the company time and money while reducing risk. DreamWorks estimates that the implementation of tape saves between 15 and 20 kilowatts per hour for each petabyte of spinning disk.

http://h30507.www3.hp.com/t5/Around-the-Storage-Block-Blog/The-opportunities-for-LTO-tape-in-the-era-of-Cloud-and-Big-Data/ba-p/181866#.VVbWypeqpBc

Week 9 Summary

- Storage – Deep Dive
  - Storage Background
  - Basic Concepts
  - Cloud Storage
  - Future Developments