Object Storage 201

Understanding Architectural Trade-offs in Object Storage Technologies

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Cloud Storage Initiative

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Today's Presenters

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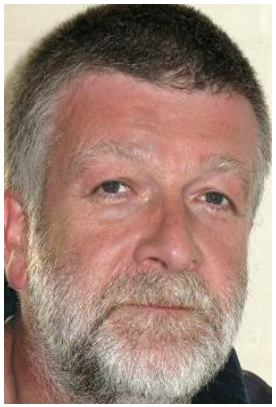

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Agenda

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- **Object store market requirements**
- How do object stores scale?
- Architectural choices for object stores
- Conclusions

Object store market requirements

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- Expected Scale
  - 100s of Billions of objects
- Performance Requirements
  - Latency (Low latency vs Medium latency workloads)
  - Throughput (High throughput vs Low throughput workloads)
- Key Features
  - Multiple sites
  - Data protection policies
  - Business logic policies
  - Erasure coding (leading to an object count explosion)
  - Multiple / complex failure domains (disk, node, rack, data center, business unit)
- Operations and Management Requirements
  - Adding nodes & sites
  - Changing capacity of existing nodes and related balancing / re-balancing
  - System upgrades and Data Migration
  - Long lived systems, with topology changes and required rebalancing

*Sources: Google: Out Mobile Planet (26 apps/phone), Intel est.

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Scale-Out Properties

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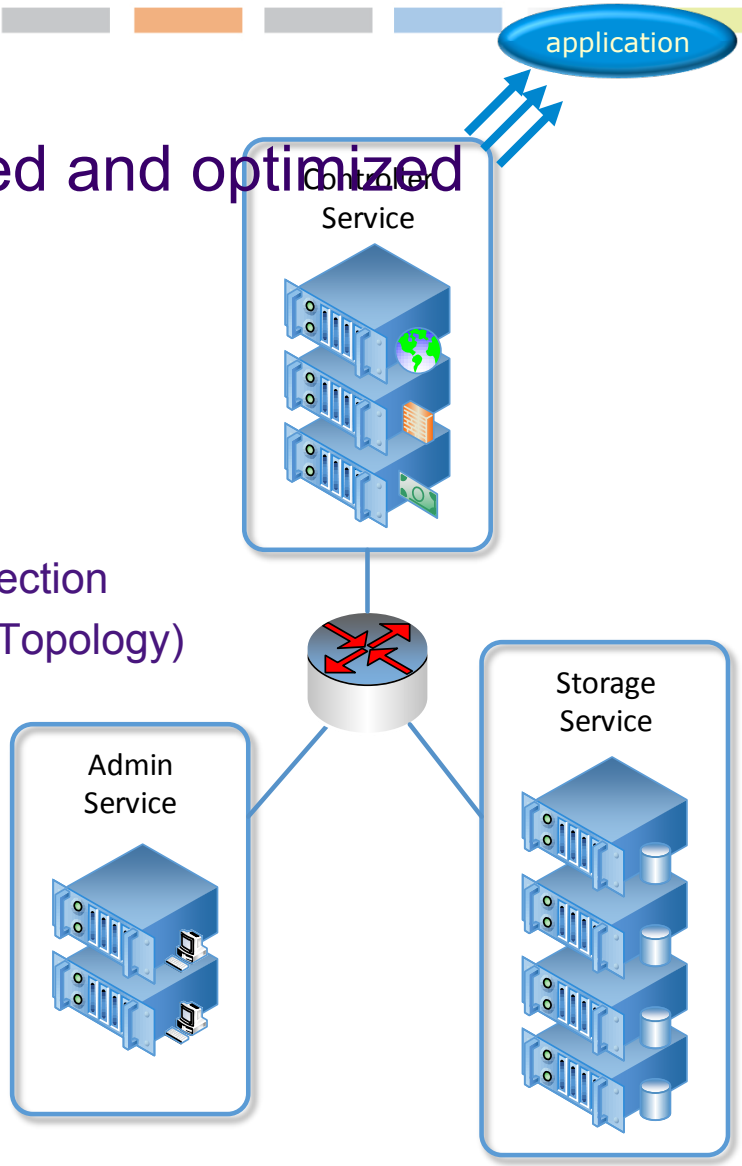
- Shared nothing architecture
- Ubiquitous Ethernet to tie things together
- Horizontally scaling of Independent services
  - Load Balancing – Load balancing across a large number of nodes
  - Placement Service – Determines location of where data needs to be placed
  - Storage Service – Basic storage service
  - Tiering and Policy management – Execute tiering & policy actions
  - Access Control, audit & security – Provide authentication, audit and security services
  - Administration and Maintenance – Handle topology changes (disks, nodes, racks, sites), expansions, contractions, hardware refreshes, system upgrades

How do Object Stores Scale? Functional Decomposition

- Essential functions are segmented and optimized for horizontal scaling
  - Controller
    - Gateway – Client interface
    - Load Balancing
    - Data Placement
    - Tiering, Policy Management & Data protection
    - System metadata Mapping information (Topology)
    - Object Metadata
  - Admin & Maintenance
    - Admin & Maintenance
  - Storage Servers
    - Information Repository

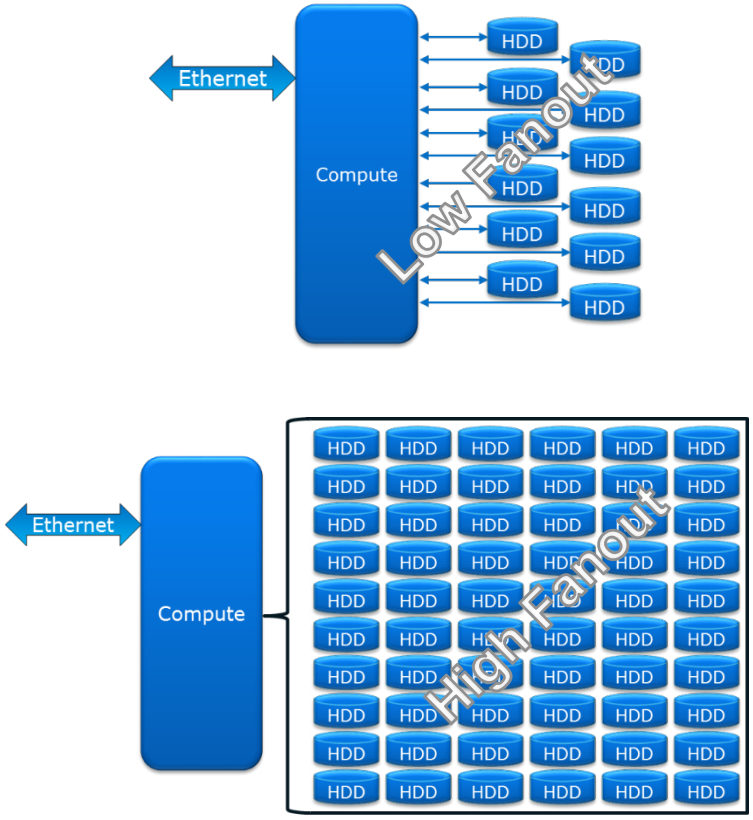


Storage Nodes - Typical

Storage Nodes store information.

Functionally they:

- Store Objects
- Support the Private Network
- Support Maintenance activities
- Defines Blast Radius

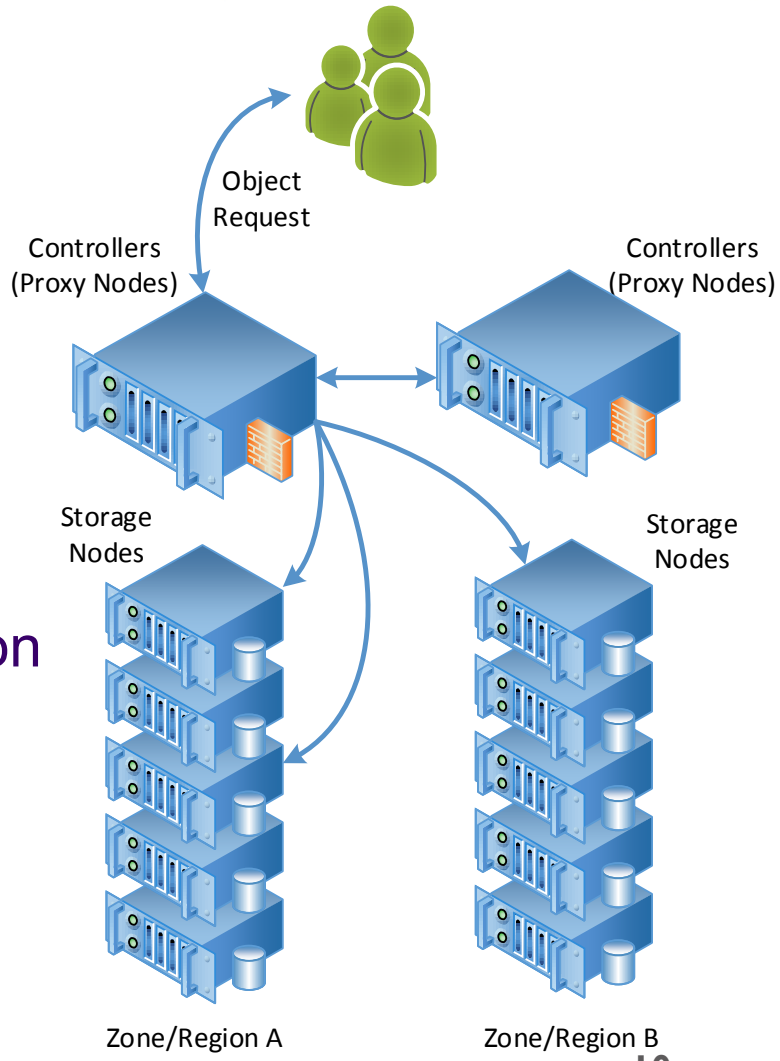


Controllers (Proxy Nodes) - Typical

Controller Nodes are the brains of the Object Store.

Functionally they:

- Provide a gateway – Client interface
- Load Balancing
- Data Placement
- System metadata Mapping information (Topology)
- Object Metadata
- Tiering, Policy Management & Data protection



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Architectural choices

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Admin Nodes

- **Admin and Maintenance procedures**

Storage Nodes

- **Information repository**

TODAY'S DISCUSSION

Architectural choices

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Storage Nodes

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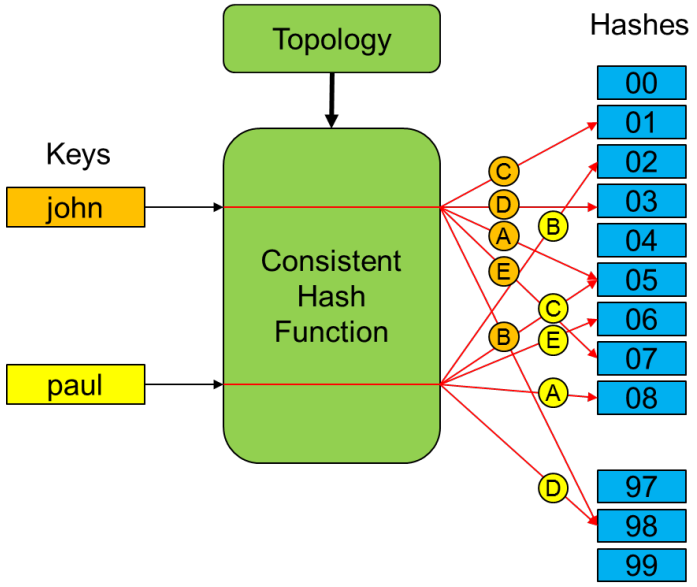
Consistent Hash

- Generates a repeatable sequence of hash values based on the input key and topology
- State Less
- Every element in the system knows data location given the Key and Topology



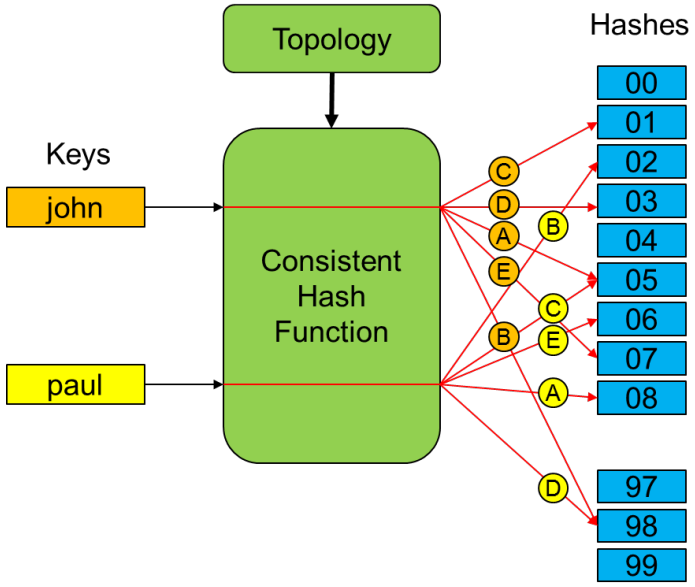
john's hash sequence:
05,98,01,03,07

paul's hash sequence:
08,02,05,98,06

Extreme Performance, Stateless, Consistent (implementations vary)

Consistent Hash

- Pros
  - State Less
  - Scales to trillions of Objects
  - Fast
- Cons
  - Consistent
  - Topology Dependent
  - Collision avoidance to guarantee uniform distribution
  - Data movement required for adding storage (Topology Change)
  - Should replace failed nodes for best performance



john's hash sequence:
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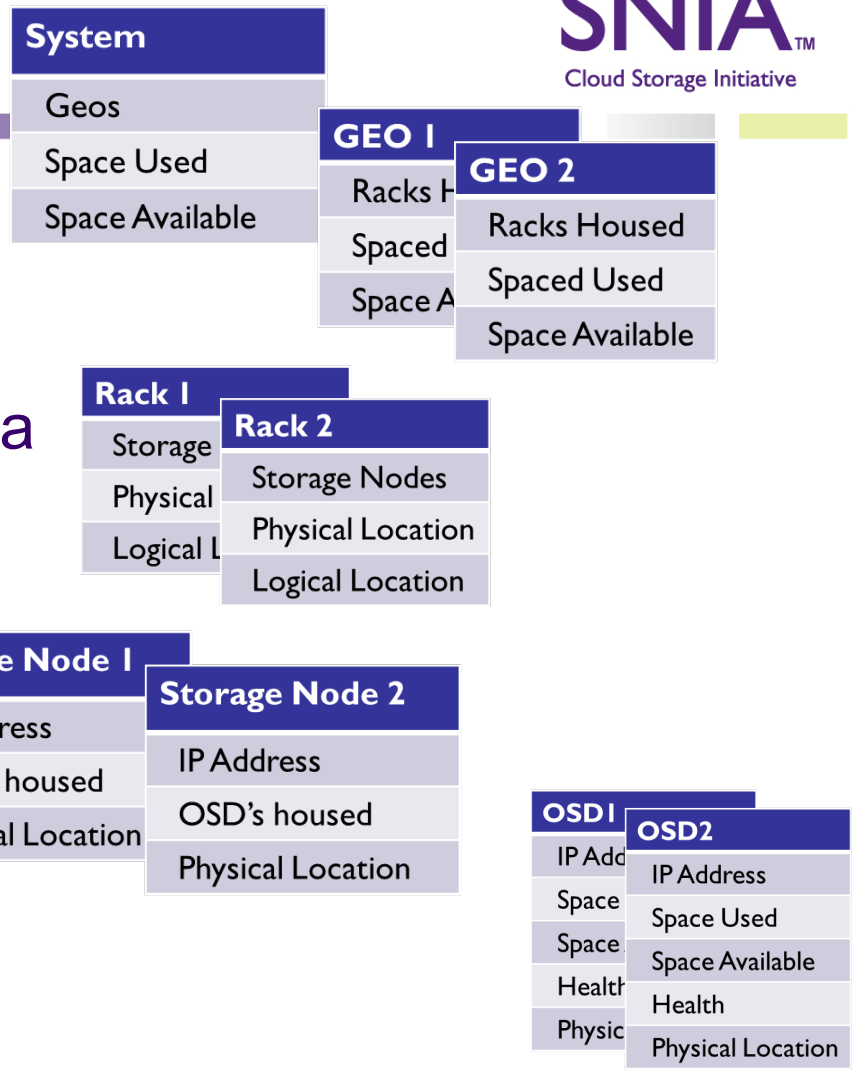
08,02,05,98,06

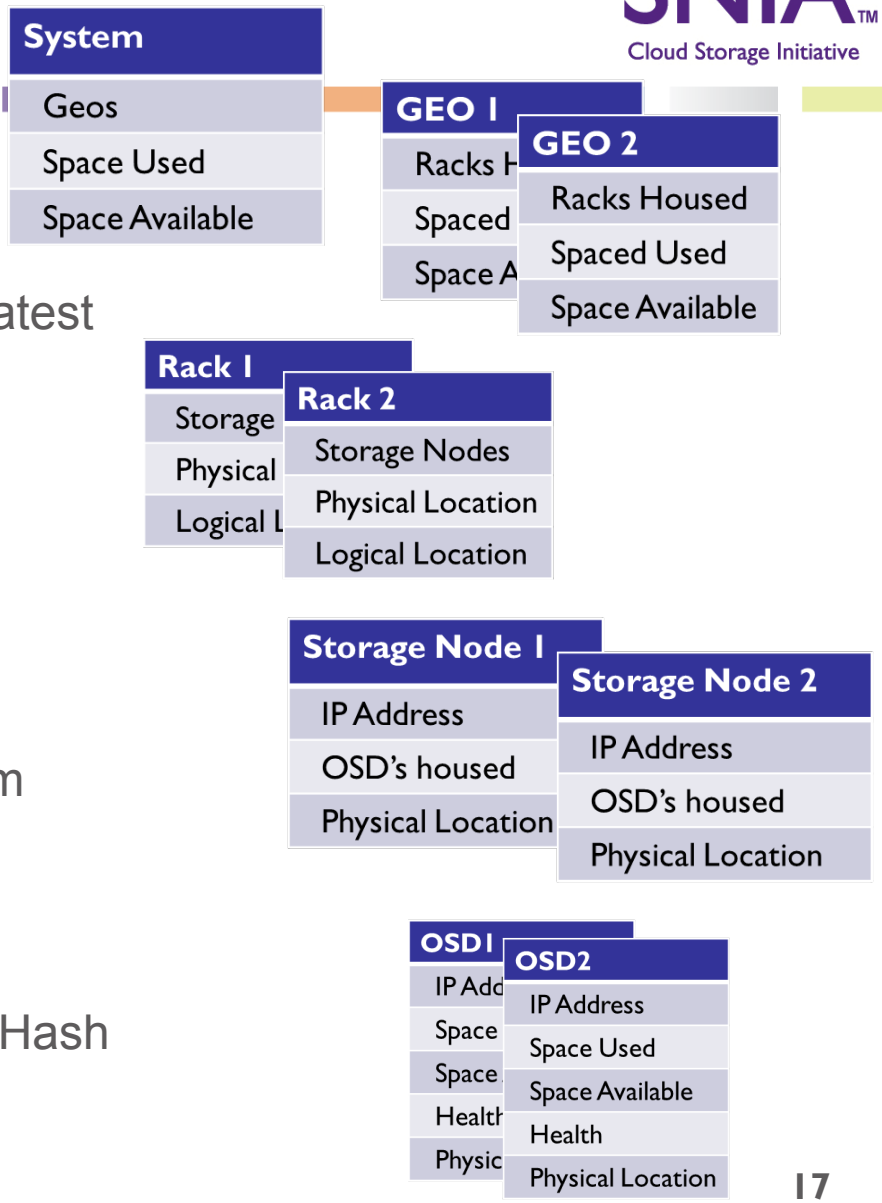
Centralized Database

- Organized collection data in structured sets that form tabular relationships between a key and a value.
- Stateful
- Located in one place



Moderately Performant, Stateful, Consistent

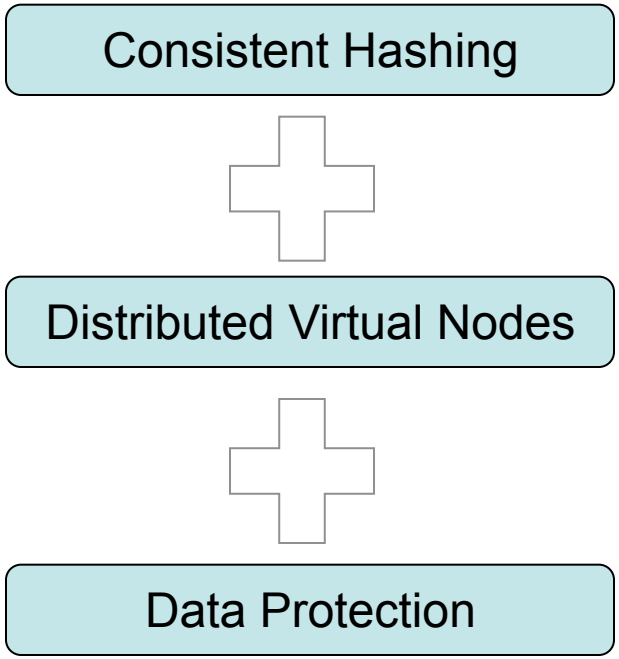
Centralized Database



- Pros
  - Consistent – always returns the latest copy
  - Flexible Placement
  - Scales to Billions of Objects
  - Maintenance and Expansion has manageable impact
- Cons
  - State Full – Needs protection from Single point of failure
  - Centralized – Bottleneck must be managed
  - Not as performant as Consistent Hash or scalable as No-SQL

NoSQL

- Databases that contain relationships other than structured tabular sets. (e.g. Key-Value, Graph, Document)
- Distributed across multiple systems
- No single point of failure



High Performance, De-Centralized, State-full, Eventually Consistent

No-SQL

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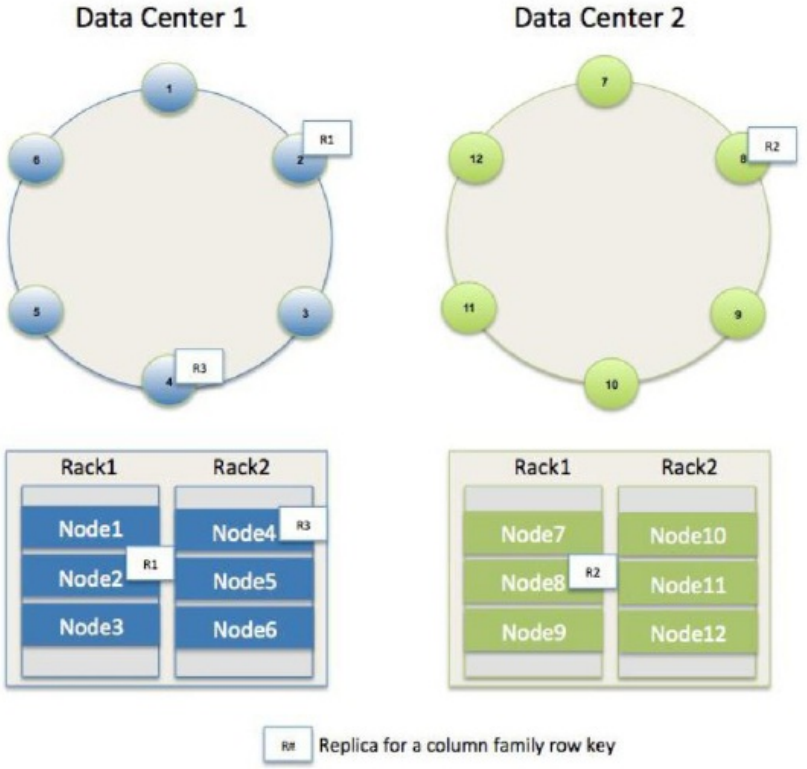
- Pros
  - Not Centralized
  - Flexible Placement
  - Scales to Trillions of Objects
  - Distributed across multiple sites
  - Partition tolerant
  - Highly performant @ scale
- Cons
  - Eventually Consistent



Data Placement Tradeoff's
Performance and scalability – Comparison of options

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Attributes	Consistent hashing	Centralized DB's	NoSQL DB's
Lookup Latency	Real time / fixed time	DB size dependent	200[1] us
Throughput	Network topology & system design	Network topology & system design	Network topology & system design
Scalability	No limit	DB size dependent	100's of Billions[2]
Consistency	Strong	Strong	Eventual
Examples	Ceph, Swift	MySql, Hadoop Name Node	MongoDB, Cassandra, HBASE

1. Assumes Cassandra with a mostly read workload with 8 shards. (http://planetcassandra.org/nosql-performance-benchmarks/) Converting Ops / Sec into latency
2. http://www.mongodb.com/scale

Architectural choices

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Controller Nodes

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Admin Nodes

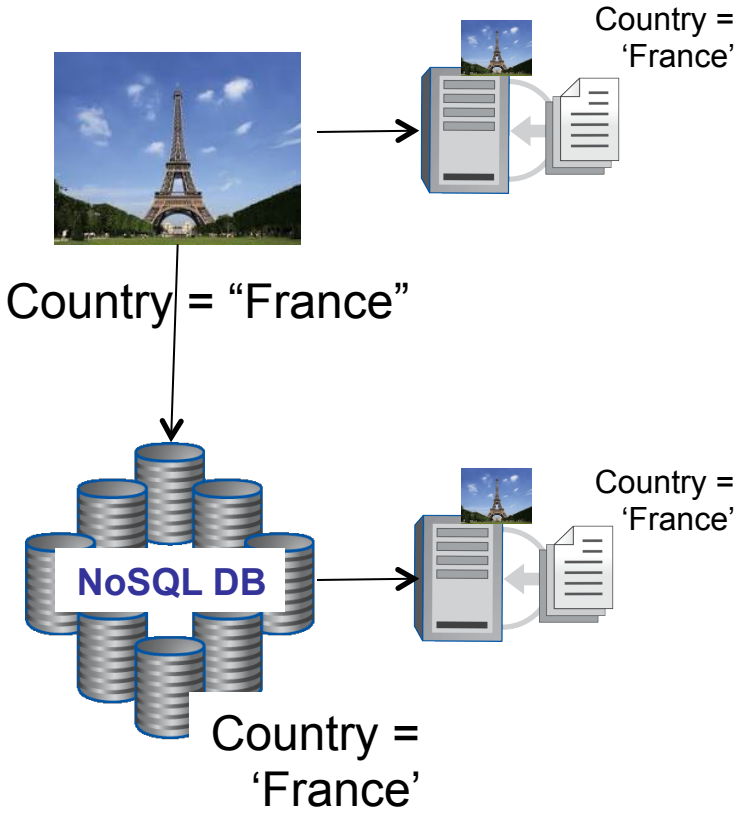
- **Admin and Maintenance procedures**

Storage Nodes

- **Information repository**

Object Meta-Data storage

- Store with the data (e.g in the XATTR of the file-system)
  - Infinitely scalable
  - Limited usability apart from serving the meta-data back to the application
- Store in a centralized database
  - Single point of failure and scalability challenges
- Store in a NoSql database
  - Scale to 100's of billions of objects
  - Policy based on business logic and application metadata
  - Analytics on the metadata



Tiering, policy management and data protection

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- Consistent Hashing – Simplistic policy
  - Keep 3 copies in Rack 1, Use erasure coding instead of replication
  - No per-object policies
  - Ingest only policy
- NoSQL & Centralized DB approaches
  - Keep 3 copies in Rack 1
  - Keep 3 copies in Rack 1 for 10 days, then keep 2 copies for 30 days, then keep 1 copy (erasure coded)
  - If Object metadata = 'CEO's email' keep 5 copies
  - If object metadata ="Europe" stay within London datacenter
  - Per object policies

Architectural choices

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Operations Maintenance and Growth

- Scenarios to consider
  - Adding a disk, node, rack, site
  - Reducing capacity of a node (Rebalance)
  - Disk, node, rack, site failure (Rebuild)
  - Hardware refresh (and migrating data to a new node)
  - Upgrade
- Hash based systems must maintain hash order when topology changes. (DIAG)
- DB Based system can re-balance over time
- Long lived systems, with topology changes and required rebalancing
  - Systems live for many generations, topology changes are common

Architectural choices

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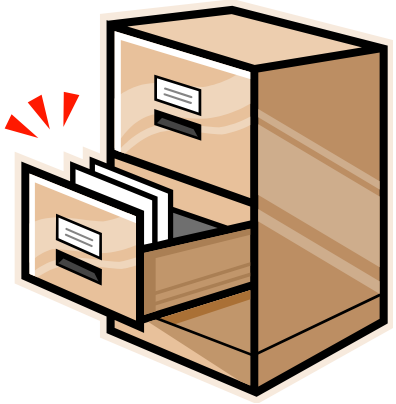
Existing file-systems vs custom file-systems

- Use existing filesystems
  - Leverage years of file-system hardening
  - Limited by / Advantages of file-system scalability at a per node level
    - EXT4 vs XFS vs BTRFS



- Custom filesystem
  - Optimize for specific use cases by reducing unnecessary file-system overhead
    - Minimize storage overhead
    - Reduce operating system latency
    - LevelDB/RocksDB

Streaming vs Store & forward architectures

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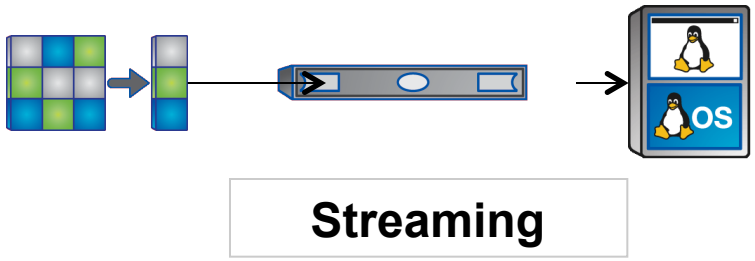
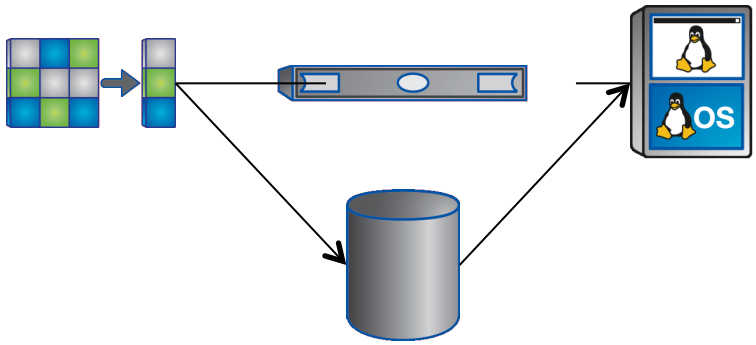
- Streaming vs Store & Forward
  - Write - Do not wait for a full object to be written, before you make placement decisions – make them on the fly
  - Read - Do not wait for a full object to be assembled before you respond to a read
- Streaming architectures
  - Lower time to first byte
  - Enabling scaling to very large object sizes
  - Compress and encrypt data on the fly
  - Can restore lost fragments instead of whole objects
  - Ability to support random reads
- Store and forward architectures
  - Lower complexity



Streaming



Store & Forward

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Performance and scalability in the real world

- Real world performance
  - Most object storage latencies in the 10's of ms
  - Limited by WAN & LAN latencies / throughput
  - At scale - Object sizes matter, data protection schemes matter
- Real world scalability
  - Ability to handle topology changes (disks, nodes, racks, sites), expansions, contractions, hardware refreshes, system upgrades
  - Real world scale – trillions of objects vs 100's of billions, single name-space versus 5 namespaces ?
- Real world consistency
  - Use case specific decision – Simultaneous modification of same object needs strong consistency properties

Architecture tradeoffs

- Simple to deploy
- Scalable
  - How the systems scale beyond a few PBs,
- Manageable
  - How will they be managed across multiple years and deployments
- Flexible
  - Ability to incorporate new features and capabilities

Object storage
"Market Requirements" versus "Your requirements"

- Expected Scale
  - 100s of Billions of objects
- Performance Requirements
  - Latency (Low latency vs Medium latency workloads)
  - Throughput (High throughput vs Low throughput workloads)
- Key Features
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After This Webcast

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- This webcast and a copy of the slides will be posted to the SNIA Cloud Storage Initiative (CSI) website and available on-demand
  - http://www.snia.org/forum/csi/knowledge/webcasts
- A full Q&A from this webcast, including answers to questions we couldn't get to today, will be posted to the SNIA-CSI blog
  - http://www.sniacloud.com/
- The original “Object Storage 101” webcast is available on-demand at the SNIA-ESF website http://www.snia.org/forums/esf/knowledge/webcasts

Conclusion

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Thank You