Using leading-edge building blocks to deploy scale-out data infrastructure

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Abstract

Using leading-edge building blocks to deploy scale-out data infrastructure

- Every datacenter includes a set of software and hardware infrastructure building blocks assembled to provide data storage, processing, and networking resources to a set of application workloads. New types of workloads, and new Commercial Off-The-Shelf infrastructure building blocks, are being developed at an increasing rate.

- These building blocks include a new generation of infrastructure software that can pool and provision hardware resources dynamically, via automation driven by policy and analytics, across a constantly changing and heterogeneous workload mix, at datacenter scale. This enables radical improvements in efficiency and effectiveness of hardware resource usage.

- Using technical (not marketing) language, and without naming specific products, this presentation covers key storage-related architectural choices and practical considerations for deploying scale-out data infrastructure using the most advanced COTS building blocks.
This presentation

- Slides will be available via Web
  - www.snia.org/education/tutorials
  - Slide sharing site; use favorite search engine
- Big topic
  - I will highlight some key points
- Please feel free to ask questions
## Scale-out data infrastructure: example hardware resources, 2015

### Components
- Small #types, highly replicated
- Physically smaller: faster, less energy

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### Nodes
- Small #configs cover many use cases
- Differ in processor, network, storage

- Network-optimized server node (“Switch”)
- General-purpose server node

### Pods
- #nodes/pod: from <10 to >1000
- Scale-out: multiple pods, sites

- Interconnect topology
- Physical layout
Software to manage resources across multiple nodes, pods, sites

Operating system software

- Virtualize & pool infrastructure resources, provision to dynamic set of app workloads
- 1950s: early single-node OS
- 2015: very active development on OS for multi-node/pod/site scale-out infrastructure
  - Most advanced: largest infrastructure & application hosting providers; tools used in-house only
  - Many Open Source & commercial efforts, mostly focused on one of processing, networking, storage
  - Open Source examples
    - Processing: Apache Mesos, HTCondor, Kubernetes, OpenStack Nova, SLURM
    - Networking: Floodlight, ONOS, OpenDaylight, OpenStack Neutron
    - Storage: Ceph, GlusterFS, Lustre, OpenAFS, OpenStack Swift, PVFS
“Software-defined” infrastructure, networking (SDN), storage (SDS), etc.

- Objection: infrastructure not “defined” by any single “thing”

- Many very distinct meanings, including:
  - Better multi-node/pod/site scale-out OS software is becoming available
  - Unbundling of integrated hardware+software “appliance” products
    - Enabled by ecosystem of G & N node hardware products with common hardware/software interfaces
    - Processing: unbundling happened years ago; choice of OS & general-purpose apps on G nodes
    - Networking: unbundling happening now; choice of OS & network-services software on G & N nodes; see also Network Function Virtualization (NFV)
    - Storage: unbundling happening now; choice of OS & storage-services software on G & N nodes
This presentation: focused on scale-out storage (SoS) software platforms

More specifically:
- Resource-management software platforms, running on scale-out clusters of server nodes, that create & provision pools of virtualized storage resources

Key characteristics
- Unified name / address space for files / blocks / objects
- Cluster nodes based on general-purpose server hardware
- Nodes interconnected via general-purpose networks
- Can grow storage capacity incrementally by adding nodes
- Can grow storage access performance incrementally by adding nodes
“Cambrian explosion” of SoS software platforms

- Well over 50 SoS software platforms currently available
  - Many more in development, various levels of stealth; fast-moving target
  - Many available products very young; small base of field experience
  - Lots of marketing & counter-marketing noise

- Why is this happening now?
  - Growth in demand for storage capacity & access performance
  - Radically better hardware for storage, processing, networking
  - Diaspora of distributed-systems expertise, e.g. from the largest hosting providers

- Key trends
  - Ambition to cover wider range of workloads with a single platform
  - Built-in workload & platform analytics; one key enabler is flash media
  - Automation driven by analytics & policy
Challenge: choosing one of 50+ available SoS software platforms

- You / your clients might benefit greatly from SoS
- Your aggregate storage workload is probably complex
- Each of 50+ available SoS platforms is complex
- How well could each platform support your workload?
  - Depends on many complex interactions between two complex things
  - Only way to find out is to actually test it
  - Such testing is resource-intensive; might be feasible to do POC / bake-off for one or two platforms
How to down-select from 50+ SoS platforms, to a small number?

- Understand your own storage workloads
- Talk with people familiar with specific SoS platforms, ask lots of questions
  - Users
    - Real-world experience
    - Use cases probably don’t exactly match yours
  - Vendors, integrators
    - Focused on specific SoS platforms, but incentive to find good product-customer fit
    - Understanding of your storage workloads helps them give you better advice
Agenda

- Understanding your storage workloads
- Some questions you can ask to help with SoS platform down-select
Understanding your storage workloads

- Tools to capture & analyze I/O traces from running workloads
  - blktrace for Linux/GNU platforms
  - Tracing & analysis tools for commercial OS & virtualization platforms
  - Tools to analyze traces & estimate/simulate effect of storage platform parameters (e.g., cache sizes) on app performance
  - Use traces to help understand:
    - How fast each application would run if latency of all I/O operations was zero
    - How application performance degrades as I/O operation latency increases
    - Per-application IOPS and I/O throughput as a function of I/O operation latency
Understanding your storage workloads

❖ At block level, look at:
  - Sequential vs. random read & write requests
  - Read & write distributions across request size
  - Read & write distributions across request time; frequency, interleaving
  - Read & write distributions across address space; working set

❖ At file/object level, also look at:
  - Distribution of file/object sizes
  - Distribution of file/object lifetimes
  - Create & delete operation distributions across request time

❖ At file level, also look at other metadata operations:
  - Distribution of #entries per directory
  - Directory operation distributions across request time
Understanding your storage workloads

- At datacenter / service provider level, also look at:
  - How many distinct tenants? How many concurrently active?
  - How many distinct applications? How many concurrently active instances of each application?
  - What storage-specific SLA requirements must be met?
  - How are #tenants, #apps, storage footprint growing over time?
Agenda

- Understanding your storage workloads
- Some questions you can ask to help with SoS platform down-select
SoS platform down-select questions

- These highlight some of many significant capability differences among currently available SoS platforms
  - Far from a comprehensive list; just scratching the surface
  - Easy to come up with many additional questions

- Collectively, currently available SoS platforms have many capabilities
  - Individually, no single SoS platform currently does more than a small subset
    - Lots of “We don’t do that”
    - Lots of “On the roadmap”

- Need to decide which are most important for your use cases
SoS platform down-select: some questions

- Interfaces: API semantics?
- Interfaces: network / wire protocols?
- Networking?
- Capacity scaling & pricing?
- Performance scaling & pricing?
- Cluster node roles?
- Storage media support?
- Data placement & movement?
- Management & monitoring?
- Workload & platform analytics?
- Automation?
- Data durability?
- Data integrity?
- Data efficiency?
- Data services?
- Fault resilience?
- Multi-site replication?
- Continuous availability?
- Online node addition & removal?
- Security?
- Multitenancy?
- Cluster node config flexibility?
- Heterogeneous cluster configs?
- In-cluster app workload support?
- Packaging options?
- Consumption options?
SoS platform down-select questions

Storage interfaces: API, semantics?

- In many cases, applications difficult/impossible to change
- If a platform doesn’t support application interfaces you need, it’s out
- Basic API types
  - Block
  - Object
  - File, e.g., POSIX
  - VM-image
- Consistency semantics
  - E.g., variations on “strong”, “eventual”
- Semantics of individual operations
  - E.g., file locking
- Cross-API capabilities
  - E.g., individual data object accessible via multiple interfaces, such as Object & File
SoS platform down-select questions

- **Storage interfaces: network / wire protocols?**
  - Block, e.g. iSCSI
  - File, e.g., NFS v.x, SMB v.x
  - Object, e.g., Swift, S3
  - Custom
    - Specific to individual SoS platform
    - Enable capabilities beyond what is possible with other protocols
    - Needs client-side agent
    - What client platforms are supported?
      - Operating systems?
      - Bare-metal, container virtualization platforms, hypervisor virtualization platforms?
      - Kernel-space client agent available?
      - User-space client agent available?

- **Cross-protocol capabilities**
  - E.g., storage volume accessible via multiple protocols, such as NFS & SMB
SoS platform down-select questions

- Networking?
  - If a platform doesn’t support network interfaces that you need, it’s out
  - Standards
    - E.g., Ethernet 10/25/40/100 Gbps, InfiniBand 32/56/100 Gbps
  - Topologies
    - Separate networks for intra-cluster traffic & client access?
      - Not supported, optional, or mandatory?
    - Redundant links & N nodes, to eliminate single points of failure?

- Acceleration / SDN
  - N nodes include programmable acceleration hardware (e.g., TCAM) that can make line-rate packet forwarding decisions based on packet-header pattern matching
  - Some SoS platforms use SDN techniques to program this hardware, to help accelerate storage I/O operations
SoS platform down-select questions

- Capacity scaling & pricing?
  - If a platform’s capacity scaling & associated economics not workable for your use cases, it’s out
  - Scaling limits
    - Pay attention to what has actually been tested/validated, vs. theoretical limits or “unlimited”
    - Min & max supported #nodes per cluster
    - Max volume/container size
    - Max object/file size
  - Usable vs. raw capacity
    - Affected by data durability strategies
    - Affected by data efficiency strategies, interacting with workload characteristics
  - Street pricing related to capacity
    - Per usable TByte in each of years 1..n for purchase, support/subscription
SoS platform down-select questions

- **Access-performance scaling & pricing?**
  - If a platform’s access-performance scaling & associated economics not workable for your use cases, it’s out
  - Scaling efficiency
    - Transactions, throughput
    - Challenge claims of “linear scaling”
  - Measuring access performance: difficult during down-select
    - First choice: vendor uses tool to replay your workload traces
    - Second choice: you specify benchmark & parameters, vendor runs it
    - Third choice: vendor-supplied benchmark results
      - At least require basic details, e.g. for IOPS measurement, get read/write mix, block size, working set size, concurrent latency measurement
  - Street pricing related to access performance
    - Per usable [GByte/sec | IOPS] in each of years 1..n for purchase, support/subscription
    - If using vendor performance claims, this is lower bound at best
SoS platform down-select questions

- **Cluster node roles?**
  - Each node may perform one or more roles, including:
    - Cluster management/monitoring
    - Gateway / proxy / client-access
    - Metadata storage & management
    - Data storage & management
  - Each role must be replicated across multiple nodes for availability
  - To make smaller deployments practical, need to be able to combine multiple roles in each node
SoS platform down-select questions

Storage media support?

- Some media options:
  - DRAM, DDR<\text{n}> interface
  - Flash, DDR<\text{n}> interface
  - Flash, PCIe/NVMe interface
  - Flash, SATA/SAS interface
  - HDD, SATA/SAS interface
  - Storage hosted outside of cluster, Ethernet interface

- If only in-cluster solid-state media supported:
  - Point solution
  - Typically also need at least one separate platform that includes support for lower-cost media
  - Data silos
  - Manual tiering
SoS platform down-select questions

- Data placement & movement?
  - Within & among nodes
  - Tiering vs. caching
  - Do writes go to highest-performance media first?
  - Rebalancing after node addition/removal/failure
SoS platform down-select questions

✍ Management & monitoring?
  ✦ Interfaces
    › GUI
    › CLI
    › API
    › Are GUI and CLI implemented entirely on top of API, so all capabilities are available via all interfaces?
  ✦ Integrations with other infrastructure management & monitoring tools
    › E.g., tab in virtualization-platform console
  ✦ Remote services offered by vendor and/or hosting providers
    › Phone-home
SoS platform down-select questions

- Workload & platform analytics?
  - Better analytics facilitated by
    - Better processors & media (flash)
    - Improved data structures & algorithms for metadata & analytics
    - Now feasible to:
      - Capture & retain full workload traces for long periods
      - Support online queries that older systems can’t support

- Example queries
  - Latency, throughput, IOPS correlated over time
  - For file/object: capacity use over time
  - For tiering/caching: hit rate per tier/cache layer, as a function of layer capacity

- Granularity of queries
  - Per client
  - For file access: per file, per subtree
  - For virtualized clients: per VM
SoS platform down-select questions

✦ Workload & platform analytics
  ✦ Predictive analytics
    › Pattern recognition, learning algorithms
    › Automatically promote specific data to higher tier in advance of predicted access
    › Recommend addition of hardware resources to avoid predicted shortfalls in storage capacity, access performance
    › Recommend remedial actions in advance of predicted component failures

✦ Automation?
  ✦ Analytics helps administrators gain insight into workload and platform behavior, make decisions, & take action manually
  ✦ Next step: options to help automate simpler decisions & actions
    › Baked-in policy options for common situations
    › Simple rule systems
    › API to provide access to system state & analytics results, enable arbitrary decision logic to drive actions
SoS platform down-select questions

▸ Data durability?
  ◆ “The universe hates your data”
    ◦ Challenge to maintain pools of low entropy
  ◆ Estimated time to data loss
    ◦ Uncomfortable topic for vendor, but should be willing & able to discuss with you
  ◆ Commonly used mechanisms
    ◦ Replication
    ◦ Erasure coding: typically slower access, more space-efficient
  ◆ Control & automation
    ◦ E.g., migration of data between replicated & erasure-coded pools
    ◦ Can be based on policies, access statistics
SoS platform down-select questions

Data integrity?

- Hardware & software sometimes do bad things to data
- Storage-media failure mode examples
  - Read
    - Wrong address
    - Data error
  - Write
    - Wrong address ("wild write")
    - Data error
    - No-op ("lost write")
- Bit flips in network
- End-to-end mechanisms to detect & correct write & read errors along full path from applications to storage media
SoS platform down-select questions

- Data efficiency?
  - Thin provisioning
  - Deduplication
  - Compression
  - Inline vs. post-process
  - Performance tradeoffs
    - Inline compression & dedupe typically add latency to datapath
    - Benefits are workload-specific
  - Control & automation
    - Enable/disable data efficiency mechanisms at per-workload granularity, based on policy, online workload analysis
SoS platform down-select questions

- Data services?
  - Snapshots
  - Clones (writeable snapshots)
  - Backups
  - Object/file versioning
  - Differences among available implementations
    - Performance of each operation
    - Limitations, e.g. max number of snapshots/clones
  - Integration with virtualization platforms
SoS platform down-select questions

- Fault resilience?
  - Rebuild after media or node failure/replacement
    - Impairment of access performance during rebuild
    - Impairment of rebuild performance based on application load during rebuild
  - Sending new writes to flash helps performance of HDD rebuilds
  - Random disconnect/reconnect test
    - Network cables
    - Power cables
    - Storage-media modules
  - Configurable failure domains
    - E.g., rack-awareness – ensuring that replicas of an object are spread across at least two racks, to maintain object availability in the event of power loss affecting a single rack
SoS platform down-select questions

- Multi-site replication / federation?
  - Synchronous / metro
  - Asynchronous
  - Bidirectional replication, for active/active site operation
  - Vendor spec for max network latency
  - Built-in WAN optimization
  - Integration with other tools to orchestrate site failover/failback
SoS platform down-select questions

ביע Continuous availability?

- No maintenance windows
- No data wipe on software/firmware upgrades
- No-downtime in-service upgrades
  - Software
  - Firmware
    - Server (BIOS, platform controllers, power supplies, etc.)
    - Storage controllers
    - Storage media modules
  - Automated, rolling across cluster
  - Rollback of failed upgrades

虱 Continuous availability?

- Online, no-downtime, no-admin addition, removal of nodes?
  - Automatic redistribution/rebalancing of existing data
  - Automatic expansion, contraction of capacity pools
SoS platform down-select questions

- **Security?**
  - Encrypted data at rest
  - Encrypted data in motion
  - Encryption key management
  - Resistance to various types of attacks, incl. DoS

- **Multitenancy?**
  - Multiple independent, untrusted clients
  - Client isolation
  - Policy-driven Quality of Service
    - Management of SLA constraints
    - Admission control
SoS platform down-select questions

- **Cluster node configuration flexibility?**
  - **Storage media modules**
    - DRAM, DDR<n> interface
    - Flash, DDR<n> interface
    - Flash, PCIe/NVMe interface
    - Flash, SATA/SAS interface
    - HDD, SATA/SAS interface
  - **Processors**
  - **Network interfaces**
    - Ethernet 10/25/40/100 Gbps
    - InfiniBand 32/56/100 Gbps
SoS platform down-select questions

❖ Heterogeneous cluster configurations?

❖ Within a single technology generation
  ➢ Performance-optimized nodes
    – Solid-state media
    – More processing & networking resources
  ➢ Nodes configured to minimize lifecycle cost per unit of capacity
    – Magnetic media, possibly with spin-down capability
    – Fewer processing & networking resources

❖ Across multiple technology generations
  ➢ Ability of platform architecture to take full advantage of upcoming technologies
    – Storage media, processing, networking
    – Radically lower latency at hardware level
  ➢ Collapsing commonly using storage software stacks
    – Need to reduce latency in software stacks, order to benefit from latency reductions at hardware level

❖ Node-specific distribution of application workload within SoS cluster
  ➢ Driven by node-specific resource profiles
SoS platform down-select questions

- In-cluster application workload support?
  - “Hyper-convergence”: just one of many possible features for SoS
  - Move computation to data, not vice versa
  - Example use cases
    - Read-intensive distributed parallel analytics
    - Storage-latency intolerant workloads
      - E.g., some financial-services apps
    - Virtual Desktop Infrastructure
  - Execution environments for application workloads
    - Bare metal
    - Container-based virtualization platforms
    - Hypervisor-based virtualization platforms
SoS platform down-select questions

❖ Packaging options?
  - Integrated hardware+software appliances
    ➢ Key advantage
      – Configurations tested/validated by vendor
  - Software, combined with hardware by integrator or end-user
    ➢ Key advantages
      – Can choose commonality with existing hardware infrastructure
      – Can take advantage of price competition among hardware suppliers
      – Can take advantage of new hardware generations sooner
    ➢ Hardware platforms
      – Hardware Compatibility List
    ➢ Hosted-infrastructure platforms
      – E.g., Infrastructure as a Service providers
SoS platform down-select questions

❖ Consumption options?
  ❖ Capacity-based
  ❖ Access-based
  ❖ Purchase + maintenance
  ❖ Service subscription
  ❖ CAPEX vs. OPEX
    › Vendor marketing mistakenly makes assumptions about end-user preferences
    › Ask the CFO!
Summary

- You / your clients might benefit greatly from SoS
  - Implemented via a software platform running on a cluster of general-purpose server units interconnected by switch server units
- Number of available SoS software platforms is well over 50, & growing
- Only way to really know how well a specific SoS platform will support specific set of workloads, is to test it
  - Resource-intensive; typically feasible to test at most one or two
- This presentation: suggestions to help down-select from 50+
  - Understanding your storage workloads
  - Some questions you can ask about specific scale-out storage platforms
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