IBM Storage & SDI

Spectrum Scale Erasure Code Edition

SC19

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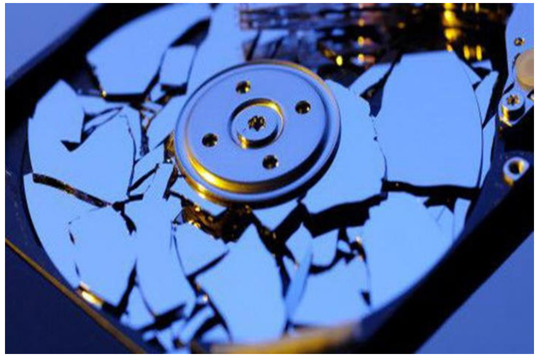
Storage-rich Servers are Growing Rapidly, Driven by…

- **Supplier mandates**
  - “We buy from Dell, HP, Lenovo, SuperMicro – whoever is cheapest at that moment”
  - “Our designated configuration is HPE Apollo”
  - “We assemble our own servers that are OCP compliant”
- **Technical and architectural mandates**
  - “This is for an analytical grid where the IT architecture team only allows x86”
  - “We need a strategic direction for scale-out storage”
  - “Only storage rich servers are acceptable, no appliances”
  - “We use storage arrays today and we are forced by upper management to go with storage rich servers”
- **Cost considerations**
  - “We want the economic benefits of commodity hardware”
  - “We don’t want to pay for high-end or even mid-range storage”

Challenges with Commodity Server Based Distributed Storage



- **Poor storage utilization**: Hadoop/Spark and other applications often have 3 replicas to protect data from hardware or software failures, resulting in low storage efficiency (33%) and thus higher costs

- **High failure rates**: Higher failure rates of commodity hardware means poor reliability, less availability, longer disk rebuild times and more impact to performance w/o SW RAID.

- **Data integrity concern**: With large volumes of data in commodity drives in commodity servers, the possibility of silent data disk corruption becomes much higher than in traditional storage systems at a smaller scale

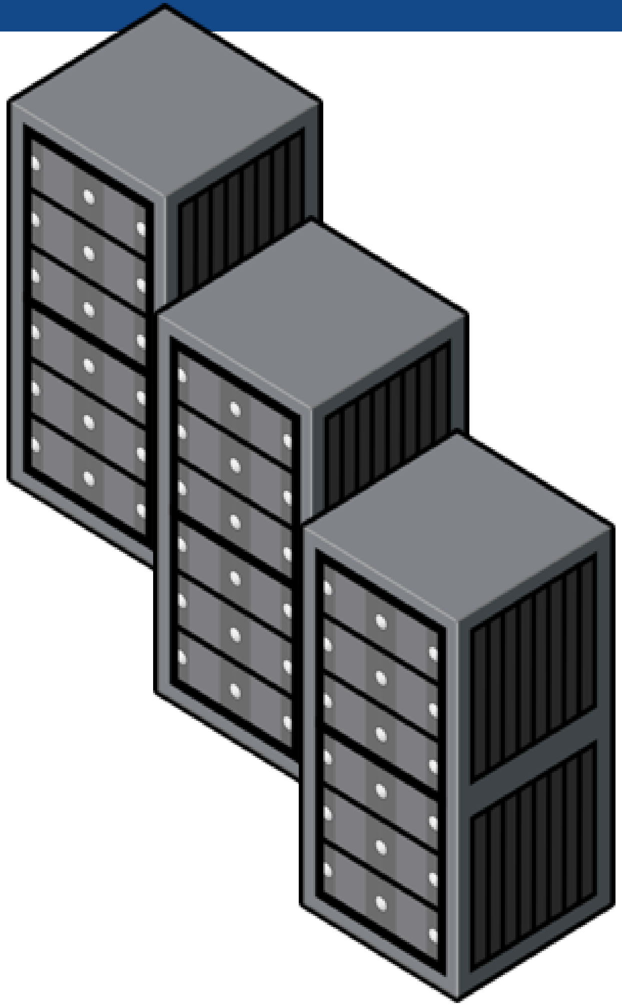
- **Scalability challenges and data silos**: Some distributed storage systems may not be able to scale or be managed easily when approaching Petabyte capacity server farms, resulting in inefficiencies and potentially unnecessary data movement

- **Missing enterprise storage features**, e.g. data life cycle management, snapshots, backup/restore, disaster recovery, disk management, encryption, etc.

- **NAS Only Support**: Lack of POSIX compliant capabilities, limited performance of traditional file systems

Spectrum Scale Erasure Code Edition

What is Spectrum Scale Erasure Code Edition?



A new Spectrum Scale offering that brings all of the benefits of “Data Management Edition” *plus* **Spectrum Scale RAID**

- Spectrum Scale running in storage rich servers connected to each other with a high speed network infrastructure
- Bring your own hardware – select any hardware that meets minimum requirements
  - Provides Storage devices can be HDD, SSD, NVMe or a mixture
- features of an Enterprise Storage Controller all in software
  - Enterprise ready storage software used in Spectrum Scale Elastic Storage Server (ESS)
- Restricted GA June 2019 *

* Required to verify supported hardware configuration

IBM Spectrum Scale Erasure Code Edition

Delivers all the capability of Spectrum Scale Data Management Edition

- Enormous scalability with Software-based declustered RAID protection
- Very high performance no additional RAID hardware
- Enterprise manageability

Plus: Durable, robust, and storage-efficient

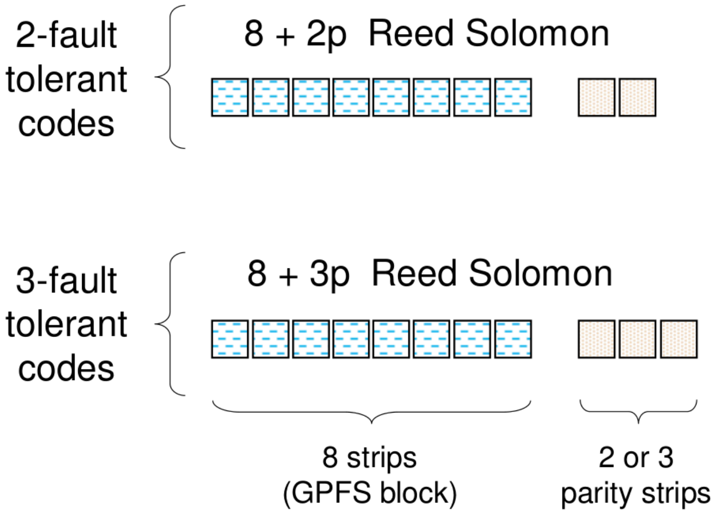
- Distributes data across nodes and drives for higher durability *without* the cost of replication
- End to end checksum identifies and corrects errors introduced by network or media
- Rapid recovery and rebuild after hardware failure

Plus: Delivered at hyperscale

- Hardware platform neutrality -Supports the user’s choice of commodity servers and drives
- Disk Hospital manages drive issues before they become disasters
- Continuous background error correction supports deployment on very large numbers of drives

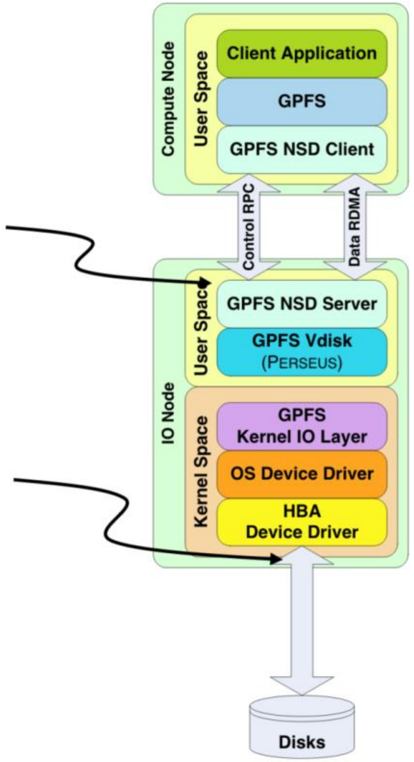
Erasure Coding Edition Reed Solomon Code Options

- ECE supports several erasure coding options and brings much better storage efficiency, with 8+3p and 8+2p Reed Solomon Code
- New erasure coding options include 4+2P and 4+3P
- Better storage efficiency means less hardware and SW costs, which can help customers to save on budgets without compromising system availability and data reliability.
- ECE erasure coding can better protect data compared with traditional RAID5/6
  - e.g. a configuration of 3 nodes of fault tolerance in an 8+3p mode, with 11 or more nodes, which can survive concurrent failure of multiple servers and storage devices.
- IBM’s ECE high performance erasure coding can be used in a first tier of storage or stand-alone. High performance on commodity servers is a key differentiation compared with other erasure coding implementations in distributed storage systems.



Spectrum Scale ECE – Scaling Out Architecture

- Spectrum Scale ECE software replaces any server based hardware controller or software RAID
  - Use any hardware that meets minimum requirements*
- Scale capacity by:
  - Adding drives to each server
  - Adding servers to a recovery group server set
- When adding servers, you are also scaling other critical resources
  - CPU, Network and PCI bandwidth, memory



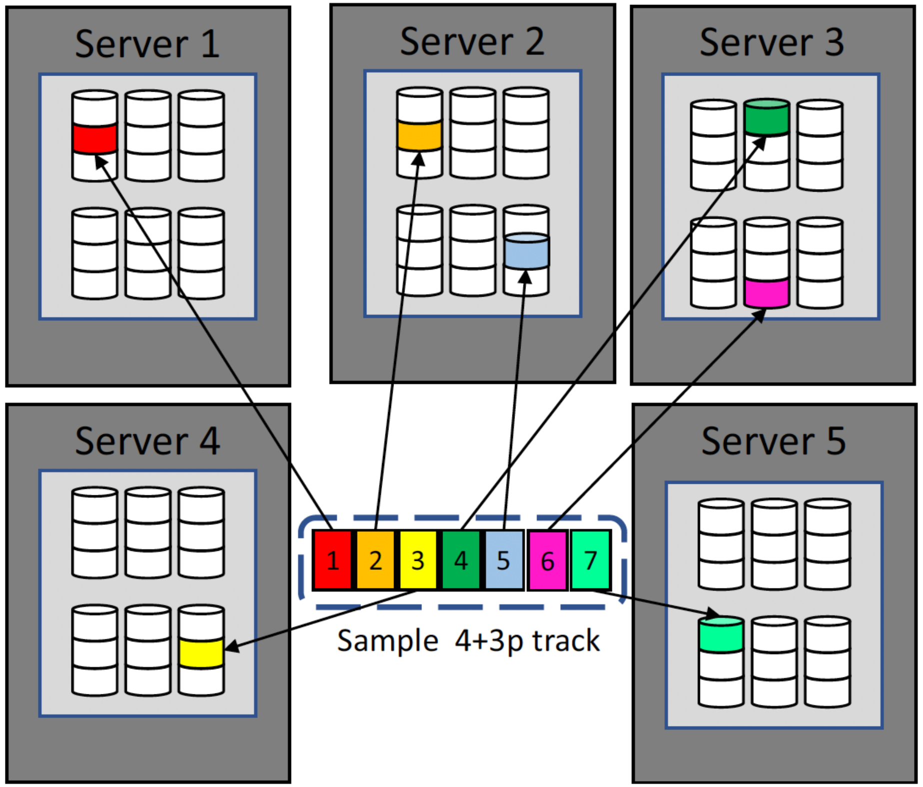
Add GNR software controller

Remove hardware controller

* See following slides

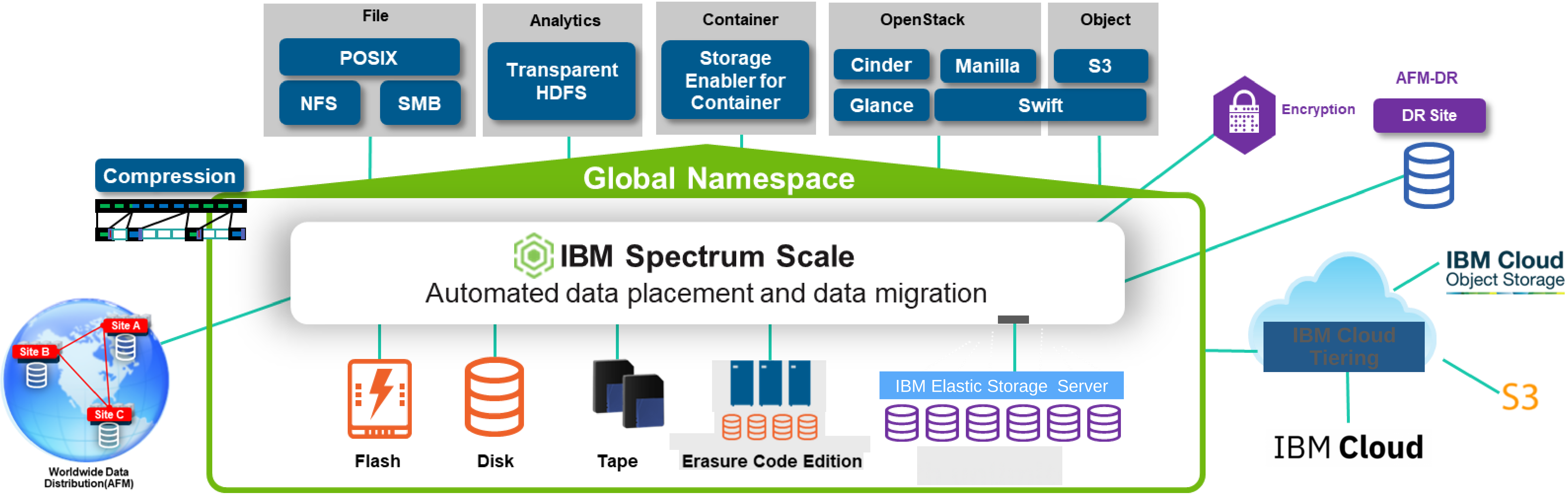
Data Distribution Across Nodes

- Tracks are distributed across the nodes in a recovery group
- Ability to tolerate multiple node and device failures while preserving access to the data
  - Number of concurrent failures is determined by the stripe size and the number of nodes



ECE Storage Pool Coexistence with IBM Spectrum Scale

Unleash new storage economics on a global scale



Highest Performance Storage with Diverse Access Protocols *using hardware that you select*

Consolidate all your unstructured data storage on spectrum scale with unlimited and painless scaling of capacity and performance

ECE is based on Proven IBM Spectrum Scale software

The software in ECE has been field-proven in over 1000 deployed ESS systems

ESS is the storage power behind the fastest supercomputers on the planet

- Summit and Sierra supercomputers at Oak Ridge National Laboratory and Lawrence Livermore National Laboratory are ranked the #1 and #2 fastest computers in the world
- They are helping to model supernovas, pioneer new materials, and explore cancer, genetics and the environment, using technologies available to all customers

ECE delivers the same capabilities on commodity compute, storage, and network components

ECE USE CASES

ECE Use Case: Dedicated High Performance file serving

- Spectrum Scale Server high performance file services deployed on storage rich nodes communicating to native Spectrum Scale clients

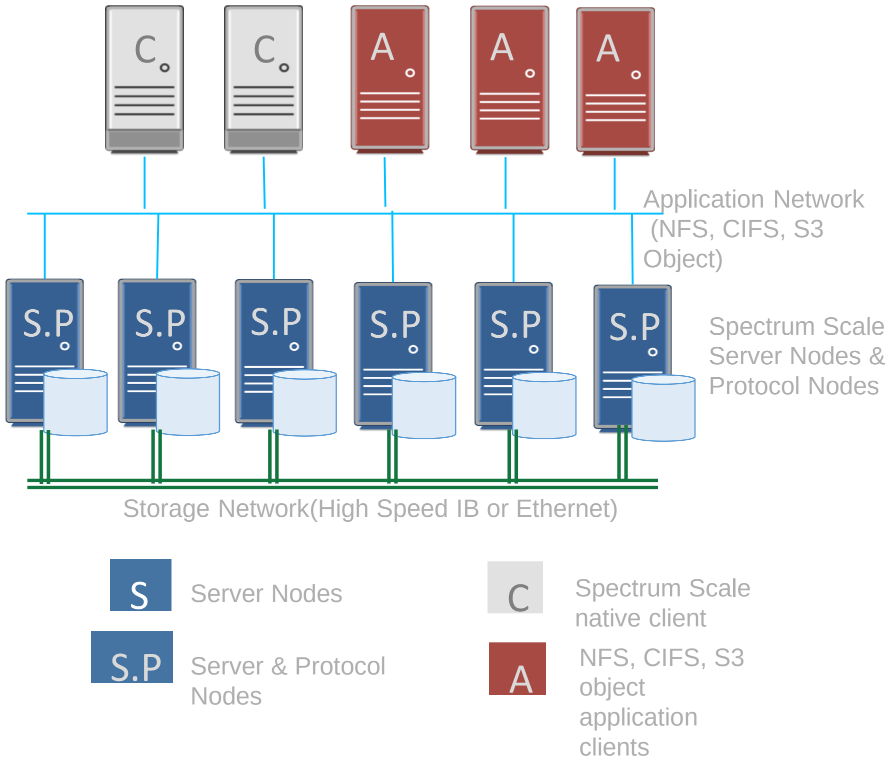
- Deploy IBM Spectrum Scale Protocol services to allow customers to access ECE with NFS, SMB and Object.

- Dedicate High speed IB or Ethernet for NFS/SMB/storage communication

- Accelerate data processing by leveraging enterprise NVMe drives to deliver high throughput and low latency

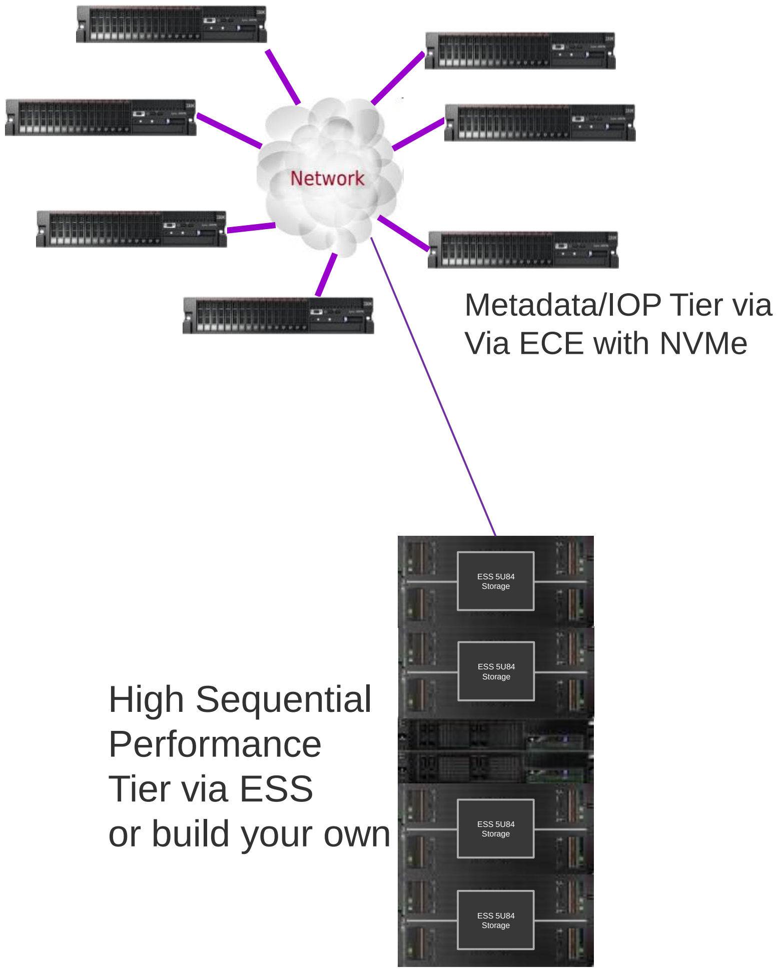
- Each ECE storage server is typically configured with several NVMe drives to store and accelerate Spectrum Scale metadata and small data I/O, combined with a number of HDD drives to store user data.

- With the high performance design of ECE, it can deliver high performance file serving to the customer workloads.


C
C
A
A
A
Application Network (NFS, CIFS, S3 Object)
S.P
S.P
S.P
S.P
S.P
S.P
Spectrum Scale Server Nodes & Protocol Nodes
Storage Network(High Speed IB or Ethernet)
S
Server Nodes
S.P
Server & Protocol Nodes
C
Spectrum Scale native client
A
NFS, CIFS, S3 object application clients

ECE Use Case: High Performance Compute tier

- ECE’s high performance erasure coding provides the capability of being a tier 1 storage device that can then tier to different storage medias (e.g. flash drives, spinning disks, tape, cloud storage, etc.) with different performance and cost characteristics.
- The policy based Information Life Cycle management feature makes it very convenient to manage data movement among different storage tiers.
- In this example, the ECE high performance compute tier is composed of NVMe drives to store and accelerate Spectrum Scale metadata and the set of hot data for high performance computing and analytics. The second tier can consist of NL SAS drives for lower $/TB and fast sequential performance.



Metadata/IOP Tier via
Via ECE with NVMe

High Sequential
Performance
Tier via ESS
or build your own

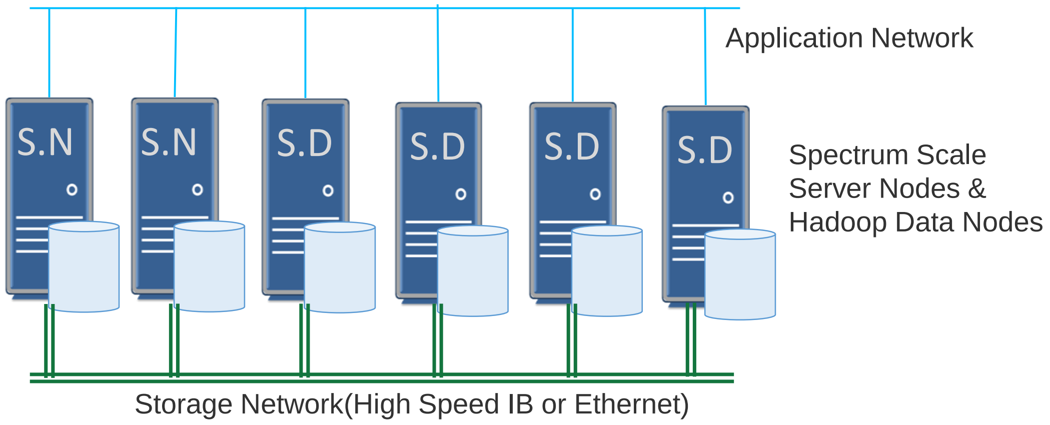
ECE Use Case: Analytics

Deployment Model:

- Spectrum Scale Server and Transparency nodes (Name Node and Data Node) are deployed in storage rich server
- Dedicate High speed IB or Ethernet for storage communication (optional but highly recommended)

Use Case:

- Analytics workload based on HDP (or even Cloudera)
- Enterprise storage of HDFS alternative

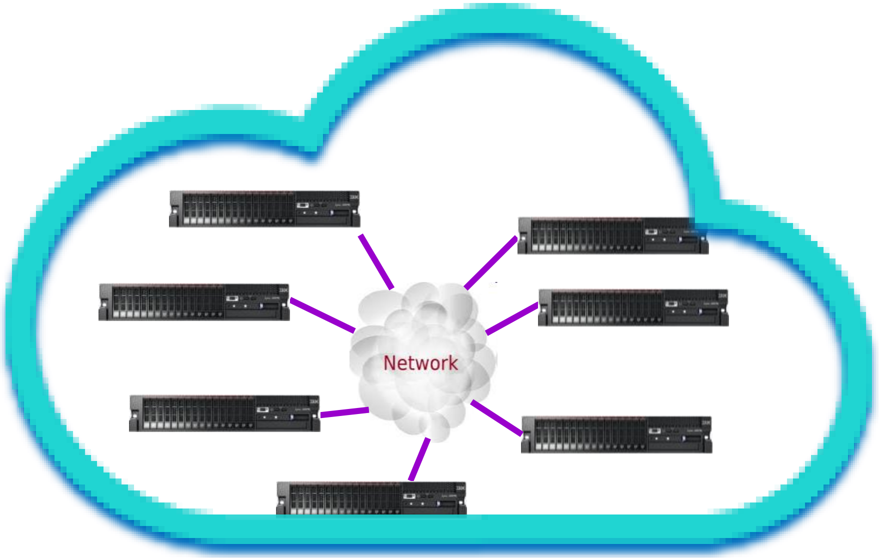

Application Network
S.N
S.N
S.D
S.D
S.D
S.D
Spectrum Scale Server Nodes & Hadoop Data Nodes
Storage Network(High Speed IB or Ethernet)

S.N Spectrum Scale Server & Transparency Name Node

S.D Spectrum Scale Server & Transparency Data Node

ECE Use Cases: High Capacity Cloud Storage

- With space efficient erasure coding and extreme end-to-end data protection design and implementation, ECE can deliver the essential cost effective and data reliability value-adds to large scale cloud storage systems.
- The ECE storage system for high capacity cloud storage may be composed of an NVMe storage pool to store and accelerate GPFS metadata and small data I/O's, or all high capacity drives for lowest $/TB
- An ECE storage system can also be low cost cloud storage connected to an on-site Spectrum Scale cluster with AFM



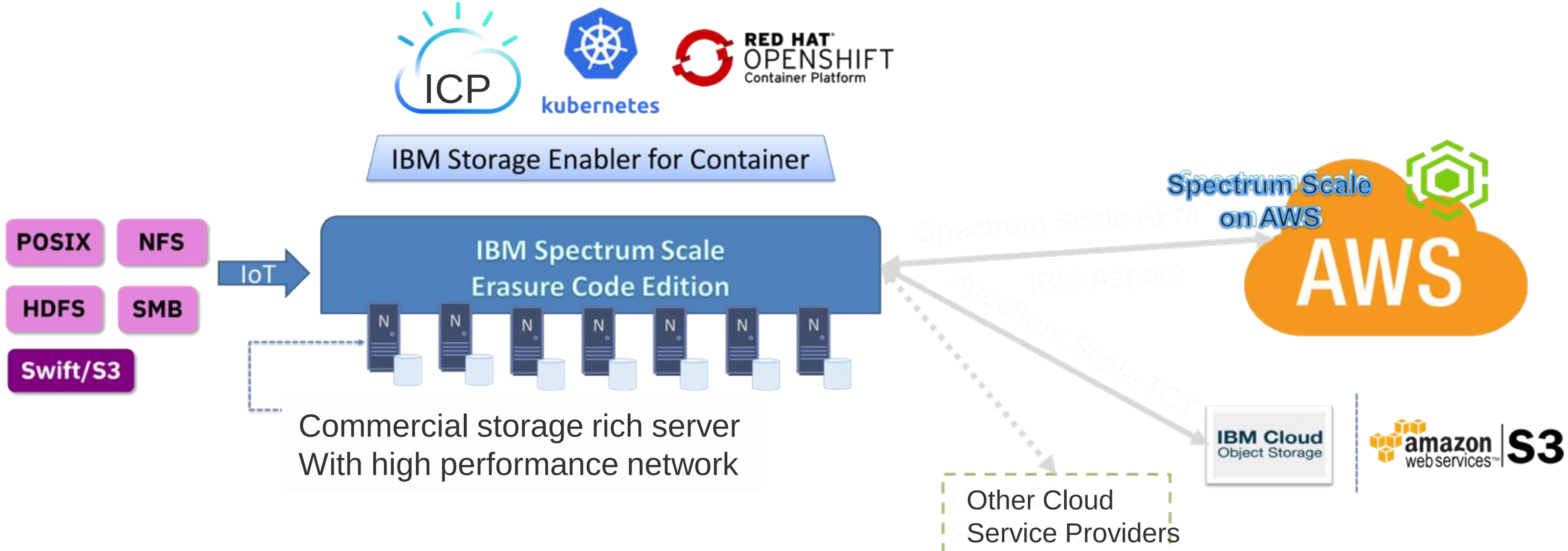
ECE Use Cases: Hybrid Multi-Cloud Storage including Containers

- ECE can provide a high performance on-prem Scale Out Filesystem and leverage containers and Kubernetes to support IBM Cloud Private, Red Hat OpenShift as well as leveraging AFM and TCT to a multitude of private/hybrid/public clouds

- Data comes from both data center and public cloud which need to be stored in a single name space to provide storage service for container

- IBM Spectrum Scale runs in both on-perm data center and AWS public cloud are connected by Spectrum Scale AFM to provide a single name space.

- Spectrum Scale with IBM Storage Enabler for Container providers storage service for container



Key Features of Erasure Coding

Erasure Coding Overview

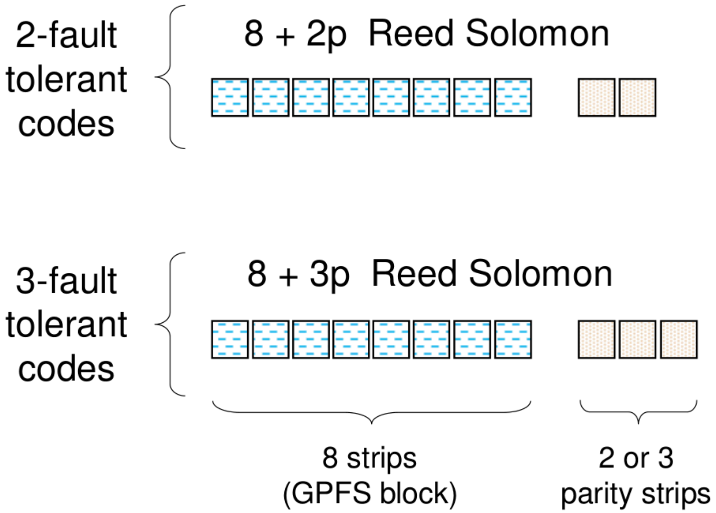
Spectrum Scale’s Reed-Solomon implementation

- For every block of data, we slice the block into K strips of equal size
- We then calculate N parity strips using RS encoding functions

- When writing data blocks, after calculating the N parity strips we store K + N total strips
  - We then distribute the data and parity strips as widely as possible across racks, servers and devices in order to minimize impact of any failure

- When reading data blocks:
  - Normal case is to read and aggregate the K data strips adding no extra overhead
  - Only rebuild data from parity strips when a lost or corrupt strip is detected
  - When possible detect and rebuild lost or corrupt data in the background

- Reed-Solomon error correction and erasure coding allows data to survive loss (erasure) or data error (correction) in up to N strips



2-fault tolerant codes

8 + 2p Reed Solomon

3-fault tolerant codes

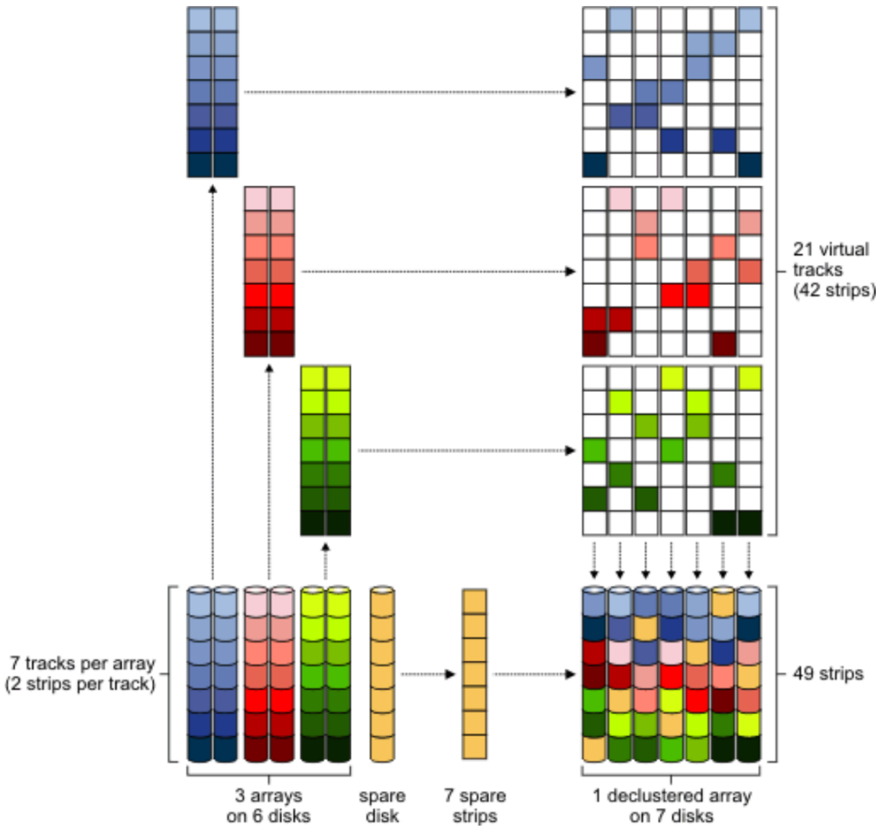
8 + 3p Reed Solomon

8 strips (GPFS block)

2 or 3 parity strips

Spectrum Scale Erasure Code Advantages

- Declustered erasure coding provides for data and parity to be distributed over all the disks and nodes in the declustered array for fastest performance out of the chosen media
  - Faster and more intelligent rebuild operations, using more drives in parallel
  - Prioritize normal vs critical conditions to better use node resources
  - Spare capacity is also distributed across all drives and nodes, so no dedicated spare disks are needed
- Improved storage efficiency and performance
  - 8+2P and 8+3P utilize less overhead vs 100% - 200% for 2X-3X replication
  - Patented algorithms optimize I/O data paths, read and multi-layer write caching


21 virtual tracks (42 strips)
7 tracks per array (2 strips per track)
49 strips
3 arrays on 6 disks
spare disk
7 spare strips
1 declustered array on 7 disks

Spectrum Scale Erasure Code - Disk Hospital

- ➢ Identify device problems before hard drive failure:
  - Dead or misbehaving disks
  - Connectivity issues
  - Media errors
  - Slow drives
- ➢ Attempt corrective action to revive sick or failing devices:
  - Power cycle non-responsive drives
  - Recompute and rewrite corrupted data
  - Rediscover disk connectivity
- ➢ Maintain “health record” for each device
  - If device is accumulating too many errors, remove from service
  - If device is persistently slow, remove from service

Spectrum Scale Erasure Code - Integrity Management

- *Every IO* has a checksum added to data trailer
- For writes, verify data integrity when data passes from
  - Client (compute node) to storage node
  - Storage node to storage media
  - Writes also include a sequence number in the metadata to detect dropped/skipped writes
- For reads, verify data integrity when data passes from
  - Storage media to storage node
  - Storage node to client
- A background scrub task periodically detects and fixes silent data corruption on the storage devices
- Automatic data rebuild on failure, automatic rebalance on recovery or when new storage is added
- Rebuild has minimal impact on system performance
  - Rebuild is distributed across disks and nodes
  - Rebuild can be deferred with sufficient protection
- Failure domain for high hardware failure tolerance

ECE Hardware Requirements

ECE Hardware/Architecture Requirements

ECE software is hardware platform neutral, but there are hardware requirements.

- An ECE storage system must have at least 4 servers, and up to 128 servers (128 is a test limitation in the first release.)

- Customers can create multiple ECE recovery groups. Each recovery group limits the number of servers to between 4 and 32.

- Customers may scale out their ECE storage system with one server, multiple servers or a whole building block.

- Every server in a recovery group must have the same configuration in terms of CPU, memory, network, storage, OS, etc.

- For SSD and NVMe drives, it is recommended to use a file system block size of 4M or less with 8+2P or 8+3P erasure codes, and 2M file system block size or less for 4+2P or 4+3P erasure codes.

- Minimum Declustered Array (DA) size DA is : At least one DA must contain 12 or more drives [1]
    - A DA is a subset of the physical disks within a recovery group that have matching size and speed.
    - A recovery group may contain multiple declustered arrays, which are unique (that is, a pdisk must belong to exactly one declustered array
    - The minimum DA size is met by each node contributing a uniform number of disks. That means a 4 node RG must have one DA with 3 or more drives per node. A twelve node RG could have one drive per node, but that drive must be a “fast device”, either SSD or NVMe.

- Each node must have at least one fast device (NVMe or SAS SSD)

- All nodes/HBA's/drives in a Recovery Group must meet minimum firmware level requirements specified in Hardware Selection and Sizing Guide. (Tested number of drives per Recovery Group: 512)

- To deliver the best performance, stability and functionality the next chart lists the minimal hardware requirements for each storage server. (This list will be expanded over time).

ECE Hardware Requirements for each Storage Server

as of November 2019*

CPU architecture	x86 64 bit processor with 8 or more processor cores per socket. Server should be dual socket with both sockets populated
Memory	•64 GB or more for configurations with up to 24 drives per node. For NVMe configurations, it is recommended to utilize all available memory DIMM sockets to get optimal performance. •For server configurations with more than 24 drives per node, contact IBM® for memory requirements.
Server packaging	Single server per enclosure. Multi-node server packaging with common hardware components that provide a single point of failure across servers is not supported at this time.
System drive	A physical drive is required for each server's system disk. Recommend RAID1 protected and have a capacity of 100 GB or more.
SAS Host Bus Adapter	LSI SAS HBA, models SAS3108, SAS3216, SAS3508 or SAS3516.
SAS Data Drives	SAS or NL-SAS HDD or SSDs in JBOD mode. SATA drives are not supported at this time.
NVMe Data Drives	Enterprise class NVMe drives with U.2 form factor.
Fast Media Req.	At least one SSD or NVMe drive is required in each server for IBM Spectrum Scale Erasure Code Edition logging.

* For latest hardware requirements see:
https://www.ibm.com/support/knowledgecenter/en/STXKQY_ECE_5.0.3/com.ibm.spectrum.scale.ece.v5r03.doc/b1lece_min_hwrequirements.htm

ECE OS & Network Requirements for each Storage Server

as of November 2019*

Operating system	RHEL 7.5, 7.6 or 7.7. See IBM Spectrum™ Scale FAQ for details of supported versions.
Network Adapter	Mellanox ConnectX-4 or ConnectX-5, (Ethernet or InfiniBand)
Network Bandwidth	25 Gbps or more between storage nodes. Higher bandwidth may be required depending on the workload requirements.
Network Latency	Average latency must be less than 1 msec between any storage nodes.
Network Topology	To achieve the maximum performance for a workload, a dedicated storage network is recommended. For other workloads, a separate network is recommended but not required.

* For latest hardware requirements see:
https://www.ibm.com/support/knowledgecenter/en/STXKQY_ECE_5.0.3/com.ibm.spectrum.scale.ece.v5r03.doc/b1lece_min_hwrequirements.htm

Installation and Hardware Pre-check

The IBM Spectrum Scale Erasure Code Edition precheck, integrated in the installation toolkit installation, deployment or upgrade precheck. The ECE check: standalone, publicly available, open source

For IBM Spectrum Scale Erasure Code Edition, the pre-check includes the following on all scale-out nodes:

- Check CPU requirements (Server cpu type/number of sockets/number of cores
- Check memory requirements (Server memory & DIMM utilization)
- Confirm consistent, allowable disk topology
- Check OS and firmware levels
- Check whether the networking requirements including the required NIC and SAS adapters are met
- Check whether the required syscall parameters are set correctly

Installation toolkit-related prerequisites

- Ensure that networking is set up in one of the following ways.
- DNS is configured such that all host names, either short or long, are resolvable.
- All host names are resolvable in the /etc/hosts file. The host entries in the /etc/hosts file must be in the following order:<IP address> <Fully qualified domain name> <Short name>
- Passwordless SSH must be set up using the FQDN and the short name of the node

Hardware precheck - verify minimum levels and consistency across Recovery Groups via toolkit

Test results saved with install log for installation record

https://www.ibm.com/support/knowledgecenter/en/STXKQY_ECE_5.0.3/com.ibm.spectrum.scale.ece.v5r03.doc/b1lece_install_intro.htm

Erasure Code Options and Failure Tolerance

Number of Nodes in RG	4+2P	4+3P	8+2P	8+3P
4-5	Not Recommended 1 Node	1 Node + 1 Device	Not Recommended 0 Nodes	Not Recommended 1 Node
6-8	2 Nodes	2 Nodes* (Limited by RG descriptors)	Not Recommended 1 Node	1 Node + 1 Device
9	2 Nodes	3 Nodes	Not Recommended 1 Node	1 Node + 1 Device
10	2 Nodes	3 Nodes	2 Nodes	2 Nodes
11+	2 Nodes	3 Nodes	2 Nodes	3 Nodes

High Level Networking Installation Steps

- Network precheck between every ECE storage node
    - Average latency < 1 msec
    - Maximum latency < 2 msec
    - Standard Deviation < 0.33 msec

- Network KPI check for network assessment
    - Standalone (based on nsdperf)
    - Publicly available
    - Open source (nsdperf becomes opensource software)

Again, for ECE, it’s all about the network

- Spectrum Scale ECE is highly network dependent

- NSD servers receive a request (ex. Write), and will need to send the write data and parity data to pdisks on other nodes

- Latency on the network plays a large role in performance
  - A High speed, low latency storage network is essential

- Keep CES, AFM, TCT and other services on separate networks

- Ensure storage network (backend) is as fast as or faster than client network (frontend)

- Use the mmnetverify connectivity all option in the mmnetverify command in the IBM Spectrum Scale: Command and Programming Reference to ensure that your network is configured for use by IBM Spectrum Scale

Licensing

ECE Licensing

- Spectrum Scale ECE is licensed by the usable TiB
  - usable capacity defined as the capacity presented to Linux, before applying erasure coding.
  - Thus the license pricing is independent of any choice of Error Correction width.
- Spectrum Scale ECE can also be licensed by the usable PiB with a discount
- ECE licenses ordered via Passport Advantage
  - The parts are Restricted initially pending review of a client’s requirements and design

Thank you