Converged Storage Technology

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Abstract

Converged Storage Technology

This SNIA Tutorial discusses the concept of object store and key-value storage, next generation key-value converged storage solutions, and what has been done to promote the key-value standard.
Background: Object Store

- **The Device based object store**
  - Originated in CMU NASD project, Garth Gibson
  - ANSI INCITS T10, OSDv2 (SCSI extension)
- **Distributed object store**
  - Ceph Rados
  - Google GFS
  - Azure Storage Stream Layer
- **The HTTP based object store**
  - Amazon Web Service S3
  - Openstack Swift
  - Ceph Object Gateway
Background: Device based object store

- **Software**
  - Ceph OSD
  - Lustre OSS
  - Panasas OSD

- **Hardware**
  - IP Disk

- **Standard organization**
  - Linux Foundation, KINETIC Open Storage Project
Background: object store stack

User space

Kernel space

User space

kernel space

- HDD
- SSD
- Object Storage Device (OSD)
- Object Store Client (OSC)
- Block
- VFS
- File system
- Block I/O layer
- SCSI layer
- Storage node
- Storage Device
- OSD
- OSC
- User space
- Kernel space
Background: Device based key-value store

- Disk optimized key-value store
  - BerkeleyDB
  - MongoDB
  - LevelDB

- Flash optimized key-value store
  - LevelDB
  - SILT – SOSP 2011
  - FlashStore – VLDB 2010
  - FAWN-KV – SOSP 2009
  - NVMKV – co-designed with FTL, HotStorage 2014
Background: Device based key-value store

Figure 2: Categorizing Existing KV stores. This figure shows a broad categorization of existing KV stores based on primarily being hard-disk- or flash-optimized and on leveraging capabilities surfaced by modern FTLs.
Background: Distributed Key-value Store

- Distributed key-value store / NoSQL DB
  - Google Bigtable
  - HBase
  - Azure Partition Layer
  - Amazon DynamoDB
  - Cassandra
  - Redis
Back ground: Key-value Store stack

- BigTable
- Azure Partition
- Dynamo
- Cassandra
- Distributed Key value store
- Distributed Object store
- OSC
- OSD
- Key value store
- Kernel space:
  - FS
  - Block I/O layer
  - SCSI layer
  - HDD
  - SSD
- User space:
  - HDD
  - SSD
  - PCIe Flash
Background: KV Store vs Object Store

Key value store and object store are similar, but they do have differences.

<table>
<thead>
<tr>
<th></th>
<th>Object Store</th>
<th>Key value store</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key type</td>
<td>Positive integer</td>
<td>Any string</td>
</tr>
<tr>
<td>Attribute</td>
<td>Need</td>
<td>Not need</td>
</tr>
<tr>
<td>Data size</td>
<td>Big</td>
<td>Small</td>
</tr>
<tr>
<td>Metadata</td>
<td>Need</td>
<td>Not need</td>
</tr>
</tbody>
</table>

![Diagram of Object](image)
A typical converged storage architecture

- **Converged storage**
  - Integrate all kinds of Storage device to provide all kinds of storage service

- **Device layer**
  - Use local FS to manage the physical space

- **Distributed object store**
  - Distributed Replication or EC
  - Checksum, Failover

- **Distributed key-value DB**
  - Unified abstraction of storage services
Problem 1

- Complicated
  - VFS is good for abstraction, but too complicated.
  - We only need an object store
    - flat namespace
    - space management.

- Flash Performance
  - User-space & kernel space transition
  - Performance wasted by OS
  - Upper layer cannot use the features of flash
    - Atomic batch write
    - Atomic batch trim
Solve the problem

Key-value framework (KVF)
- User-space key-value library
- User-space key-value storage device
- IP-device for remote access
- Interface like VFS
  - General interface for common application
  - Extended interface for flash
- Make the lower level and high level the same interface
The KVF architecture

- KVF is a interface framework (like VFS), KVS is the actual store (like FS).
- Low level management interface: Let vendor device register in.
- Up level access interface: Let upper services to access the KVS, they can based on local KVS or Distributed KVS.
- Distributed KVS can base on local KVS and register into KVF again, like many distributed file system do.
The key value framework

What & why

- Storage vendors offload the simple KV operation (put/ get/ delete/ iterator) to the storage medium. Which make the higher level simple, high performance, low TCO.
- All KV store have similar interface, but there is no unified standard.
KVF data model

- KVS can provide different kind of containers (some vendor called pools), based on storage medium.
- On top of container, we can provide object, which can access by KV interface
- Container can nest to provide distributed container.
A kind of KVF interface

Register interface

Vendor capability interface

Container interface

s32 kvf_register(kvf_type_t * t);
s32 kvf_unregister(kvf_type_t * t);
kvf_type_t* get_kvf(const char* name);

typedef struct kvf_operations {
s32 (*init)(const char* config_file);
s32 (*shutdown)();
s32 (*set_prop)(const char* name, char* value);
s32 (*get_prop)(const char* name, char* value);
 void* (*alloc_buf)(u32 size, s32 flag);
 void (*free_buf)(void** buf);
 const char* (*get_errstr)(s32 errcode);
s32 (*get_stats)(kvf_stats_t * kvfstats);
s32 (*trans_start)(kv_trans_id_t** t_id);
s32 (*trans_commit)(kv_trans_id_t* t_id);
s32 (*trans_abort)(kv_trans_id_t* t_id);
} kvf_operations_t;

typedef struct pool_operations {
s32 (*create)(const char* name, const char* config_file, pool_id_t* pid);
s32 (*destroy)(const char* name);
s32 (*open)(const char* name, u32 mod, pool_id_t* pid);
s32 (*close)(const pool_id_t pid);
s32 (*set_prop)(const pool_id_t pid, u64 prop, const char buf[MAX_PROP_LEN]);
s32 (*get_prop)(const pool_id_t pid, u64 prop, char buf[MAX_PROP_LEN]);
s32 (*get_stats)(const pool_id_t pid, pool_stats_t* stats);
s32 (*xcopy)(const pool_id_t src, const pool_id_t dest, s32 flags, void* regex, s32 regex_len);
s32 (*list)(pool_id_t** pid, s32* num);
} pool_operations_t;
typedef struct kv_operations {
    s32 (*put)(const pool_id_t pid, const key_t* key, const value_t* value,
              const kv_props_t* props, const put_options_t* putopts);
    s32 (*get)(const pool_id_t pid, const key_t* key, value_t* value, const kv_props_t* props,
              const get_options_t* getopts);
    s32 (*del)(const pool_id_t pid, const key_t* key, const kv_props_t* props,
              s32 (*mput)(pool_id_t pid, const kv_array_t* kvarray, const kv_props_t* props,
                         const put_options_t* putopts);
    s32 (*mget)(pool_id_t pid, kv_array_t* kvarray, const kv_props_t* props,
               const get_options_t* getopts);
    s32 (*mdel)(pool_id_t pid, const kv_array_t* kvarray, const kv_props_t* props,
                 const del_options_t* delopts);
    s32 (*async_put)(pool_id_t pid, const key_t* key, const value_t* value,
                     const kv_props_t* props, const put_options_t* putopts, async_crud_cb put_fn);
    s32 (*async_get)(pool_id_t pid, const key_t* key, value_t* value,
                    const kv_props_t* props, const get_options_t* getopts, async_crud_cb get_fn);
    s32 (*async_del)(pool_id_t pid, const key_t* key,
                     const kv_props_t* props, const del_options_t* delopts, async_crud_cb del_fn);
    s32 (*iter_open)(const pool_id_t pid, s32 flags, void* regex, s32 regex_len, s32 limit,
                     iter_id_t* itid);
    s32 (*iter_next)(const pool_id_t pid, iter_id_t itid, kv_array_t* kvarray);
    s32 (*iter_close)(const pool_id_t pid, iter_id_t itid);
} kv_operations_t;
Problem 2

- Distributed layer performance
  - Kernel space block & file protocol
    - Not easy to transplant
    - Not easy to develop
    - Performance problem
  - Network package cross the OS many times, degrade performance
Solve the problem

- **User-space protocol**
  - User-space iscsi, Linux tgt
  - User-space NFS, Ganesha

- **User-space network stack**
  - Intel DPDK
  - FreeBSD Netmap
  - InfiniBand, user-space RDMA

- **End-to-end user-space I/O stack**
Distributed object store

- Distributed Hash Table: Sheepdog, Swift, etc
  - Less metadata, easy to scale-out,
  - Loss data locality
  - Difficult to provide performance isolation
  - Not easy to support policy
Distributed object store

- Master record object location: GFS, Azure Stream Layer, etc
  - Metadata bottleneck
  - Easy to support policy
  - Keep data locality
Distributed key value DB

- **DHT: Dynamo, Cassandra, etc**
  - Easy to scale out
  - Loss key-value locality
  - Easy aggregate performance

- **Range Partition: Bigtable, Azure partition layer, etc.**
  - Easy to scale out
  - Keep locality
  - Easy to isolate performance
Other concerns

- **Lock service**
  - Zookeeper
  - Chubby

- **Transaction support**
  - Local transaction
  - Distributed transaction

- **Cross datacenter in one region**
  - Sync replication

- **Cross region**
  - Asynchronous Geo-replication
The SNIA Education Committee thanks the following Individuals for their contributions to this Tutorial.

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