ABSTRACT: This SNIA document defines an application programing interface for Key Value Object drives.

This document has been released and approved by the SNIA. The SNIA believes that the ideas, methodologies and technologies described in this document accurately represent the SNIA goals and are appropriate for widespread distribution. Suggestions for revisions should be directed to http://www.snia.org/feedback/.

SNIA Technical Position
September 28, 2020
USAGE

Copyright © 2019, 2020 SNIA. All rights reserved. All other trademarks or registered trademarks are the property of their respective owners.

The SNIA hereby grants permission for individuals to use this document for personal use only, and for corporations and other business entities to use this document for internal use only (including internal copying, distribution, and display) provided that:

1. Any text, diagram, chart, table or definition reproduced shall be reproduced in its entirety with no alteration, and,

2. Any document, printed or electronic, in which material from this document (or any portion hereof) is reproduced, shall acknowledge the SNIA copyright on that material, and shall credit the SNIA for granting permission for its reuse.

Other than as explicitly provided above, you may not make any commercial use of this document or any portion thereof, or distribute this document to third parties. All rights not explicitly granted are expressly reserved to SNIA.

Permission to use this document for purposes other than those enumerated above may be requested by e-mailing tcmd@snia.org. Please include the identity of the requesting individual and/or company and a brief description of the purpose, nature, and scope of the requested use.

All code fragments, scripts, data tables, and sample code in this SNIA document are made available under the following license:

BSD 3-Clause Software License

Copyright (c) 2019, 2020, The Storage Networking Industry Association.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

* Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.

* Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.

* Neither the name of The Storage Networking Industry Association (SNIA) nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT OWNER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
DISCLAIMER
The information contained in this publication is subject to change without notice. The SNIA makes no warranty of any kind with regard to this specification, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. The SNIA shall not be liable for errors contained herein or for incidental or consequential damages in connection with the furnishing, performance, or use of this specification.
Table of Contents

1 SCOPE ...................................................................................................................... 8

2 REFERENCES .......................................................................................................... 9

3 DEFINITIONS, ABBREVIATIONS, AND CONVENTIONS ..................................... 10

3.1 DEFINITIONS ........................................................................................................ 10
3.1.1 Key Space ................................................................................................... 10
3.1.2 SSD ............................................................................................................. 10
3.1.3 key value pair .............................................................................................. 10

3.2 KEYWORDS ......................................................................................................... 10
3.2.1 mandatory ................................................................................................... 10
3.2.2 may ............................................................................................................. 10
3.2.3 may not ........................................................................................................ 10
3.2.4 need not ...................................................................................................... 10
3.2.5 optional ........................................................................................................ 10
3.2.6 shall ............................................................................................................. 10
3.2.7 should .......................................................................................................... 11

3.3 ABBREVIATIONS ................................................................................................... 11

4 OVERVIEW OF KVS API ........................................................................................ 12

4.1 OVERVIEW .......................................................................................................... 12
4.2 KEY-VALUE ENTITIES ..................................................................................... 13
4.3 KEY SPACE ......................................................................................................... 13
4.4 KEY GROUP ......................................................................................................... 14
4.5 KEY VALUE PAIR .................................................................................................. 14

5 CONSTANTS & DATA STRUCTURES .................................................................. 15

5.1 TYPES ................................................................................................................ 15
5.2 CONSTANTS ........................................................................................................ 15
5.2.1 KVS_ALIGNMENT_UNIT ............................................................................ 15
5.2.2 KVS_MAX_KEY_GROUP_BYTES ............................................................. 15
5.3 API RETURN VALUE (KVS_RESULT) .............................................................. 15
5.3.1 kvs_result .................................................................................................... 15

5.4 DATA STRUCTURES .............................................................................................. 16
5.4.1 kvs_api_version ........................................................................................... 16
5.4.2 kvs_context ................................................................................................. 17
5.4.3 kvs_key_order ............................................................................................. 17
5.4.4 kvs_option_key_space ................................................................................ 18
5.4.5 kvs_option_delete ....................................................................................... 18
5.4.6 kvs_iterator_type ......................................................................................... 18
5.4.7 kvs_option_iterator ...................................................................................... 18
5.4.8 kvs_option_retrieve .................................................................................... 19
5.4.9 kvs_store_type ............................................................................................ 19
6.1 Overview .............................................................................................................. 27

6.2 Device Level APIs ................................................................................................. 28
6.2.1 kvs_open_device.............................................................................................. 28
6.2.2 kvs_get_device_info......................................................................................... 29
6.2.3 kvs_close_device............................................................................................. 30
6.2.4 kvs_get_device_capacity............................................................................... 31
6.2.5 kvs_get_device_utilization........................................................................... 32
6.2.6 kvs_get_min_key_length.................................................................................. 33
6.2.7 kvs_get_max_key_length............................................................................... 34
6.2.8 kvs_get_min_value_length............................................................................ 35
6.2.9 kvs_get_max_value_length........................................................................... 36
6.2.10 kvs_get_optimal_value_length.................................................................... 37
6.2.11 kvs_create_key_space............................................................................... 38
6.2.12 kvs_delete_key_space................................................................................. 39
6.2.13 kvs_list_key_spaces.................................................................................... 40

6.3 Key Space-Level APIs ......................................................................................... 41
6.3.1 kvs_open_key_space...................................................................................... 41
6.3.2 kvs_close_key_space..................................................................................... 42
6.3.3 kvs_get_key_space_info............................................................................... 43
6.3.4 kvs_get_kvp_info........................................................................................ 44
6.3.5 kvs_retrieve_kvp.......................................................................................... 45
6.3.6 kvs_retrieve_kvp_async.............................................................................. 46
6.3.7 kvs_store_kvp............................................................................................... 48
6.3.8 kvs_store_kvp_async.................................................................................... 49
6.3.9 kvs_delete_kvp.............................................................................................. 50
6.3.10 kvs_delete_kvp_async............................................................................... 51
6.3.11 kvs_delete_key_group............................................................................... 52
6.3.12 kvs_delete_key_group_async..................................................................... 53
6.3.13  kvs_exist_kv_pairs ................................................................. 54
6.3.14  kvs_exist_kv_pairs_async ...................................................... 55
6.4  ITERATOR FUNCTION CALLS ................................................... 56
   6.4.1  kvs_create_iterator .............................................................. 56
   6.4.2  kvs_delete_iterator ............................................................. 58
   6.4.3  kvs_iterate_next ................................................................. 59
   6.4.4  kvs_iterate_next_async ....................................................... 60
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Key-value Hierarchical Architecture</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>Key-value Entities</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>Fixed Key Length: kvs_iterator_key</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>Fixed Key Length: kvs_iterator_kvp</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>Variable Key Length: kvs_iterator_key</td>
<td>24</td>
</tr>
<tr>
<td>6</td>
<td>Variable Key Length: kvs_iterator_kvp</td>
<td>24</td>
</tr>
</tbody>
</table>
1 Scope

This specification defines the Application Programing Interface (API) for Key Value storage devices implementing the SNIA Object Drive protocol.
2 References

The following referenced documents are indispensable for the application of this document.

For references available from ANSI, contact ANSI Customer Service Department at (212) 642-49004980 (phone), (212) 302-1286 (fax) or via the World Wide Web at http://www.ansi.org.

NVMe
PCIe
SNIA IP Based Drive Management Specification
3 Definitions, abbreviations, and conventions
For the purposes of this document, the following definitions and abbreviations apply.

3.1 Definitions

3.1.1 Key Space
A collection of Key Value Pairs identified by a name and it is a unit of management in Key Value Storage see 4.3 (e.g., in NVMe a Namespace of type KeyValue)

3.1.2 SSD
Solid State Drive

3.1.3 key value pair
Object defined by a pair of key and value

3.2 Keywords
In the remainder of the specification, the following keywords are used to indicate text related to compliance:

3.2.1 mandatory
a keyword indicating an item that is required to conform to the behavior defined in this standard

3.2.2 may
a keyword that indicates flexibility of choice with no implied preference; “may” is equivalent to “may or may not”

3.2.3 may not
keywords that indicate flexibility of choice with no implied preference; “may not” is equivalent to “may or may not”

3.2.4 need not
keywords indicating a feature that is not required to be implemented; “need not” is equivalent to “is not required to”

3.2.5 optional
a keyword that describes features that are not required to be implemented by this standard; however, if any optional feature defined in this standard is implemented, then it shall be implemented as defined in this standard

3.2.6 shall
a keyword indicating a mandatory requirement; designers are required to implement all such mandatory requirements to ensure interoperability with other products that conform to this standard

3.2.7 should
a keyword indicating flexibility of choice with a strongly preferred alternative

3.3 Abbreviations
API Application Programming Interface
KVS Key Value Storage
NVMe NVM Express (Non-Volatile Memory Express)
PCIe PCI Express (Peripheral Component Interconnect Express)
SSD Solid State Disk
4 Overview of KVS API

4.1 Overview
This document describes the Key Value Storage (KVS) Application Program Interface (API) specification for SSD storage devices with Object Drive based Key Value Storage. It provides a set of APIs that are portable across multiple vendor SSD products.

The KVS API provides management of the characteristics of the KVS instances to provide a common set of KVS instances. Once configured, all available KVS instances report the same characteristics.

Characteristics to provide to the host
1) Optimal STORE size (per key space)
2) Maximum number of keys/value size/key size/capacity (matrix) (aggregate – changes every time a Key Space is created/deleted)
3) Value granularity (per key space)
4) Minimum Key Length
5) Maximum Key Length
6) Minimum value Length
7) Maximum value Length
8) Total capacity (bytes) (aggregate and per key space)
9) Remaining capacity (bytes) (aggregate – changes every time a Key Space is created/deleted; and per key space)
10) Device Utilization

Characteristics of a device that is capable of Key Value storage are determined through a redfish implementation and allocation of a device to keyspaces is done through a KV management API. For an NVMe implementation there is at most one Keyspace per NVMe Namespace. For a SCSI implementation there is at most one Keyspace per SCSI LUN.

The library routines this document defines allow applications to create and use objects in SSDs while permitting portability. The library:
- Extends the C++ language with host and device APIs
- Provides support for Key Space, atomic operation, asynchronous operation, and callback

Library routines and environment variables provide the functionality to control the behavior of KVS. Figure 1 shows the hierarchical KVS architecture.
4.2 KEY-VALUE ENTITIES

A Key-value device is a physical or logical storage device such as a HDD, SSD, or an NVM Set which has a native storage command protocol of a key-value interface. A Key Space is created from a portion or all of a Key Value device. Form factors (e.g., 2.25", 2.5", M.2, M.3, and HHHL) or command protocols (e.g., SATA, SCSI, NVMe, and NVMeoF) are beyond the scope of this specification.

4.3 Key Space

A Key Space defines the uniqueness of keys (i.e., Keys shall be unique within a Key Space). A Key Space is associated with the specific configuration (e.g., key size, value size, capacity) with which it was created. Different Key Spaces in a device may be
created with different configurations. A Key Space contains a collection of Key Value Entities (i.e., Key Value Pairs, or Key Groups) that are managed as a single entity (e.g., NVMe namespace, SCSI LUN, or disk partition). A device is able to simultaneously have multiple Key Spaces. A Key-value device shall support at least one Key Space. A Key Space is associated with a specified amount of capacity.

4.4 Key Group
A Key Group is a logical set of Key Value Pairs within a Key Space which applications are able to dynamically create. Key Groups are optional. This is able to be used to represent a shard, a document collection, an iterator, etc. A Key Group is specified by specific bits set to a given value in the key. The Key Group may be accessed using a call that specifies a mask of the bits in the key which defines the key group field, and a key group identifier identifying which Key Group is being accessed. A Key Space is able to simultaneously have multiple Key Groups. The Key Group field starts at the MSB and the size of the key group field is of byte granularity.

4.5 Key Value Pair
A Key Value Pair is an entity consisting of a key and a value. It is a unit of access. A key is application-defined and unique within a Key Space. The key length is able to be fixed or variable and its maximum is limited. A value length is variable and its maximum is limited.
5 Constants & Data Structures

This section defines Key-value SSD core constants, data structures, and functions.

5.1 Types

5.2 Constants

5.2.1 KVS_ALIGNMENT_UNIT
This is an alignment unit. An offset of value is required to be a multiple of this value.

5.2.2 KVS_MAX_KEY_GROUP_BYTES
The maximum number of bytes used for Key Group_bytes. This is set when a device is opened (e.g., if KVS_MAX_KEY_GROUP_BYTES is 3, any 3 bytes out of a key are able to be used to define a Key Group) and is the same for all Key Spaces in the device.

5.3 API return value (kvs_result)

5.3.1 kvs_result
An API returns a return value after finishing its operation. Two types of return value are returned. One is returned after the command is sent and the other after the command completes.

Return value details are discussed in each command section.
typedef enum {
    KVS_SUCCESS 0 // Successful
    KVS_ERR_BUFFER_SMALL 0x001 // buffer space is not enough
    KVS_ERR_DEV_CAPACITY 0x002 // device does not have enough space. Key Space size is too big
    KVS_ERR_DEV_NOT_EXIST 0x003 // no device with the dev_hd exists
    KVS_ERR_KS_CAPACITY 0x004 // key space does not have enough space
    KVS_ERR_KS_EXIST 0x005 // key space is already created with the same name
    KVS_ERR_KS_INDEX 0x006 // index is not valid
    KVS_ERR_KS_NAME 0x007 // key space name is not valid
    KVS_ERR_KS_NOT_EXIST 0x008 // key space does not exist
    KVS_ERR_KS_NOT_OPEN 0x009 // key space does not open
    KVS_ERR_KS_OPEN 0x00A // key space is already opened
    KVS_ERR_ITERATOR_FILTER_INVALID 0x00B // iterator filter(match bitmask and pattern) is not valid
    KVS_ERR_ITERATOR_MAX 0x00C // the maximum number of iterators that a device supports is opened
    KVS_ERR_ITERATOR_NOT_EXIST 0x00D // the iterator Key Group does not exist
    KVS_ERR_ITERATOR_OPEN 0x00E // iterator is already opened
    KVS_ERR_KEY_LENGTH_INVALID 0x00F // key is not valid (e.g., key length is not supported)
    KVS_ERR_KEY_NOT_EXIST 0x010 // key does not exist
    KVS_ERR_OPTION_INVALID 0x011 // an option is not supported in this implementation
    KVS_ERR_PARAM_INVALID 0x012 // null input parameter
    KVS_ERR_SYS_IO 0x013 // I/O error occurs
    KVS_ERR_VALUE_LENGTH_INVALID 0x014 // value length is out of range
    KVS_ERR_VALUE_OFFSET_INVALID 0x015 // value offset is out of range
    KVS_ERR_VALUE_OFFSET_MISALIGN 0x016 //offset of value is required to be aligned to KVS_ALIGNMENT_UNIT
    KVS_ERR_VALUE_UPDATE_NOT_ALL_OWED 0x017 // key exists but value update is not allowed
    KVS_ERR_DEV_NOT_OPENED 0x018 // close a device which is not opened yet
} kvs_result;

5.4 Data Structures

5.4.1 kvs_api_version

typedef struct {
    uint8_t major; // API library major version number
    uint8_t minor; // API library minor version number
} kvs_api_version;
The `kvs_api_version` structure defines the API library version. For example the kvs_api_version for KV-API version 0.17 would be 0x001100.

5.4.2 `kvs_context`

```c
typedef enum {
    KVS_CMD_DELETE =0x01,
    KVS_CMD_DELETE_GROUP =0x02,
    KVS_CMD_EXIST =0x03,
    KVS_CMD_ITER_CREATE =0x04,
    KVS_CMD_ITER_DELETE =0x05,
    KVS_CMD_ITER_NEXT =0x06,
    KVS_CMD_RETRIEVE =0x07,
    KVS_CMD_STORE =0x08,
} kvs_context;
```

kvs_context sets up opcode in API level for key value operation.

5.4.3 `kvs_key_order`

```c
typedef enum {
    KVS_KEY_ORDER_NONE =0,    // [DEFAULT] key ordering is not defined in a Key Space
    KVS_KEY_ORDER_ASCEND, =1,    // kvp are sorted in ascending key order in a Key Space
    KVS_KEY_ORDER_DESCEND =2,    // kvp are sorted in descending key order in a Key Space
} kvs_key_order;
```

This enumeration specifies the ordering of keys returned.
• KVS_KEY_ORDER_NONE, no key order is defined in a key space.
• KVS_KEY_ORDER_ASCEND, key value pairs are sorted in ascending key order in a Key Space
• KVS_KEY_ORDER_DESCEND, key value pairs are sorted in descending key order in a Key Space

5.4.4 kvs_option_key_space

```c
typedef struct {
    kvs_key_order   ordering;   // key ordering option in Key Space
} kvs_option_key_space;
```

A user is able to define the ordering of keys returned.

5.4.5 kvs_option_delete

```c
typedef struct {
    bool      kvs_delete_error; // [OPTION] return error when the key does not exist
} kvs_option_delete;
```

The application is able to specify a delete operation option.

- kvs_delete_error set to TRUE specifies that an operation deletes the key-value pair or if the key does not exist, the device return KVS_ERR_KEY_NOT_EXIST error code. kvs_delete_error set to FALSE specifies that an operation deletes the key if it exists and always returns success even if the key does not exist.

5.4.6 kvs_iterator_type

```c
typedef enum {
    KVS_ITERATOR_KEY    =0, // [DEFAULT] iterator command retrieves only key entries without values
    KVS_ITERATOR_KEY_VALUE =1, // iterator command retrieves key and value pairs
} kvs_iterator_type;
```

5.4.7 kvs_option_iterator

```c
typedef struct {
```
5.4.8 kvs_option_retrieve

```c
typedef struct {
    bool kvs_retrieve_delete; // [OPTION] retrieve the value of the key value pair and delete the key value pair
} kvs_option_retrieve;
```

The application is able to specify a retrieve operation option.

- `kvs_retrieve_delete` set to TRUE specifies that an operation retrieves the key-value pair and the key value pair is atomically deleted after completing the retrieve. `kvs_retrieve_delete` set to FALSE specifies that an operation retrieves the key-value pair and no deletion is atomically performed.

5.4.9 kvs_store_type

```c
typedef enum {
    KVS_STORE_POST =0,  // [DEFAULT]
    KVS_STORE_UPDATE_ONLY =1,
    KVS_STORE_NOOVERWRITE =2,
    KVS_STORE_APPEND =3,
} kvs_store_type;
```

The application is able to specify a store operation option.

- **KVS_STORE_POST**: if the key exist, the operation overwrites the value. If the key does not exist, it creates the key value pair.
- **KVS_STORE_UPDATE_ONLY**: If the key exist, the operation overwrites the value. If the key does not exist, it returns KVS_KEY_NOT_EXIST error.
- **KVS_STORE_NOOVERWRITE**: if the key exist, the operation returns KVS_ERR_VALUE_UPDATE_NOT_ALLOWED. If the key does not exist, it creates the key value pair.
- **KVS_STORE_APPEND**: if the key exist, the operation appends the value to the existing value. If the key does not exist, it creates the key value pair.
5.4.10 kvs_association_type

```c
typedef enum {
    KVS_NOASSOCIATION = 0, // no association
    KVS_ASSOCIATION_STREAM = 1, // stream association
} kvs_association_type;
```

The application is able to specify an association option.
- KVS_NOASSOCIATION: no association defined
- KVS_ASSOCIATION_STREAM: key value pair associated with stream

5.4.11 kvs_associtation

```c
typedef struct {
    kvs_association_type assoc_type; // association type for a group of associated key value pairs.
    uint16_t assoc_hint; // association hint(e.g., stream id)
} kvs_associtation;
```

The application is able to specify an association type and hint.

5.4.12 kvs_option_store

```c
typedef struct {
    kvs_store_type st_type; // store operation type (refer to 5.4.10)
    kvs_association *assoc; // association (refer to 5.4.12)
} kvs_option_store;
```

The application is able to define store operation options.

5.4.13 kvs_device_handle

```c
typedef void* kvs_device_handle; // type definition of kvs_device_handle
```

A kvs_device_handle is a vendor-specific opaque data structure pointer. API programmers may define a private vendor-specific data structure, which may contain the device id and other device-related information, and use this pointer type as a device handle.
5.4.14 *kvs_key_space_handle*

```
typedef void* kvs_key_space_handle; // type definition of kvs_key_space_handle
```

A *kvs_key_space_handle* is a vendor-specific opaque data structure pointer. API programmers may define a private vendor-specific data structure, which may contain the key space id and other key space related information, and use this pointer type as a key space handle.

5.4.15 *kvs_iterator_handle*

```
typedef void* kvs_iterator_handle; // type definition of kvs_iterator_handle
```

A *kvs_iterator_handle* is a vendor-specific opaque data structure pointer. API programmers may define a private vendor-specific data structure, which contains the iterator id and other iterator related information, and use this pointer type as an iterator handle.

5.4.16 *kvs_key_space*

```
typedef struct {
    bool_t opened; // is this Key Space opened
    uint64_t capacity; // Key Space capacity in bytes
    uint64_t free_size; // available space of Key Space in bytes
    uint64_t count; // # of Key Value Pairs that exist in this Key Space
    kvs_key_space_name *name; // Key Space name
} kvs_key_space;
```

A Key Space is a unit of management and represents a collection of Key Value Pairs or Key Groups.

5.4.17 *kvs_key_space_name*

```
typedef struct {
    uint32_t name_len; // Key Space name length
    char *name; // Key Space name specified by the application
} kvs_key_space_name;
```
This structure contains Key Space name information for return value of 
kvs_list_key_space() API. The name is of length name_len and if it is null terminated 
the null is part of the length. A device is not required to check the uniqueness of Key 
Space name.

5.4.18 kvs_device

```
typedef struct {
    Uint64_t  capacity;  // device capacity in bytes
    Uint64_t  unalloc_capacity; // device capacity in bytes that has not been
                                 // allocated to any key space
    uint32_t  max_value_len; // max length of value in bytes that device is able to
                              // support
    uint32_t  max_key_len;  // max length of key in bytes that device is able to
                              // support
    uint32_t  optimal_value_len; // optimal value size
    uint32_t  optimal_value_ 
                     // optimal value granularity
granularity;
    void      *extended_info; // vendor specific extended device information.
} kvs_device;
```

kvs_device structure represents a device and has device-wide information.

5.4.19 kvs_exist_list

```
typedef struct {
    uint32_t  num_keys;  // the number of key entries in the list
    kvs_keys *keys;     // keys checked for existence
    uint32_t  length;   // input buffer size(result_buffer) and returned buffer size
    uint8_t   *result_buffer; // exist status info
} kvs_exist_list;
```

A kvs_exist_list structure is used to check whether keys exist in the KV device. The 
result_buffer field presents the existence of the keys. Each bit in the result buffer is set 
to one if the key exists and set to zero if the key does not exist.

5.4.20 kvs_key_group_filter

```
typedef struct {
    uint8  bitmask[KVS_MAX_KEY_GROUP_BYTES];  // bit mask for bit pattern to use
    uint8  bit_pattern[KVS_MAX_KEY_GROUP_BYTES];  // bit pattern for filter
```
This structure defines Key Group information for `kvs_create_iterator()` that sets up a Key Group of keys matched with a given `bit_pattern` within a range of bits defined by the bitmask and for `kvs_delete_key_group()` such that it is able to delete a group of key-value pairs. Bitmask is to be set in multiple of 8 bits starting from the MSB of the 32 bit value. For more details, see `kvs_create_iterator()` (section 6.4.1) and `kvs_delete_key_group()` (section 6.3.10).

### 5.4.21 kvs_iterator_list

```c
typedef struct {
    uint32_t  num_entries;  // the number of iterator entries in the list
    bool_t    end;         // represent if there are more keys to iterate (end =0) 
                     // or not (end = 1)
    uint32_t  size;  // the it_list buffer size as an input and returned data
                     // size in the buffer in bytes
    uint8_t   *it_list;  // iterator list.
} kvs_iterator_list;
```

`kvs_iterator_list` represents entries within an iterator Key Group. It is used for retrieved iterator entries as a return value for `kvs_iterator_next()` operation. `num_entries` specifies how many entries in the returned iterator list(`it_list`). `size` specifies buffer size of `it_list` as an input and specifies the total amount of data that is returned in bytes as an output. `end` indicates that no more iterator items exist. When `end` is zero, host would re-run `kvs_iterator_next()` to retrieve more data. `it_list` has `num_entries` of iterator elements as follows:

- **When key length is fixed**, `num_entries` entries of `<key>` when iterator is set with `KVS_ITERATOR_KEY` (Figure 3) and `num_entries` entries of `<key, value_length, value>` when iterator is set with `KVS_ITERATOR_KEY_VALUE` (Figure 4)
- **When keys have variable length**, `num_entries` entries of `<key_length, key>` when iterator is set with `KVS_ITERATOR_KEY` (Figure 5) and `num_entries` entries of `<key_length, key, value_length, value>` when iterator is set with `KVS_ITERATOR_KEY_VALUE` (Figure 6).
5.4.22 kvs_key

```c
typedef struct {
    void *key; // a void pointer refers to a key byte string
    uint16_t length; // key length in bytes
} kvs_key;
```

A key consists of a void pointer and its length. For a Key Space with variable keys (i.e., character string or byte string), the void key pointer holds a byte string without a null termination, and the integer variable of length holds the string byte count. The void key pointer is required not to be a null pointer.
5.4.23 kvs_postprocess_context

```c
typedef struct {
  kvs_context context;          // operation type
  kvs_key_space_handle *ks_hd;  // key space handle
  kvs_key *key;                 // key data structure
  kvs_value *value;             // value data structure
  void *option;                 // operation option
  void *private1;               // a pointer passed from a user
  void *private2                 // a pointer passed from a user
  kvs_result result;            // IO result
  kvs_iterator_handle*iter_hd;  // iterator handle
union {
  kvs_iterator_list *iter_list;
  kvs_exist_list *list;
} kvs_postprocess_context;
```

*kvs_postprocess_context* is IO context that carries IO information including key and value pairs and operation return value. It is mainly used for post process function.

*Note: Async is for performance benefit. Multi-thread may cover it but we could reduce system resource utilizations with higher performance. Also more scalable. E.g. SPDK.*

5.4.24 kvs_postprocess_function

```c
typedef void(*kvs_postprocess_function)(kvs_postprocess_context *ctx) // async notification callback (valid only for async I/O)
```

*kvs_postprocess_function* is able to be called and specifies the tasks needing execution once an IO operation completes. Typical post-processing tasks send a signal to a thread to wake it up to implement synchronous IO semantics and/or call an application-defined notification function to implement asynchronous IO semantics.

5.4.25 kvs_value

```c
typdef struct {
  void *value;              // start address of buffer for value byte stream
  uint32_t length;          // the length of buffer in bytes for value byte stream
  uint32_t actual_value_size;   // actual value size in bytes that is stored in a device
  uint32_t offset;          // [OPTION] offset to indicate the offset of value stored in device
```
A value consists of a void pointer and a length. The value pointer refers to a byte string without null termination, and the length variable holds the byte count. The value pointer variable shall not be a null pointer. Offset specifies the offset within a value stored in the device. The offset is required to be aligned to KVS_ALIGNMENT_UNIT. If not, a KVS_ERR_VALUE_OFFSET_MISALIGNED error is returned.

5.4.26 kvs_kvp_info

```c
typedef struct {
    uint16_t    key_len;  // key length in bytes
    uint8_t*    key;      // key
    uint32_t    value_len; // value length in bytes
} kvs_kvp_info;
```

This data structure contains key value pair properties associated with a key.
6 Key Value Storage APIs

6.1 Overview
This clause defines the core data structures for key-value device. A Key Space may be allocated from a single storage device, a storage array, an entry point into a cloud storage device or any other device that implements the KVS API. A Key Space is created using the kvs_create_keyspace API call. The Key Space is then opened using the kvs_open_keyspace API call.
6.2 Device level APIs

6.2.1 kvs_open_device

\texttt{kvs\_result kvs\_open\_device ( char *\texttt{URI}, kvs\_device\_handle *\texttt{dev\_hd})}

This API opens a KVS device. This API internally checks device availability and initializes it. It returns zero if successful. Otherwise, it returns an error code.

**PARAMETERS**

<table>
<thead>
<tr>
<th>IN</th>
<th>URI</th>
<th>Universal Resource Identifier of a device</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUT</td>
<td>dev_hd</td>
<td>device handle</td>
</tr>
</tbody>
</table>

**RETURNS**

KVS\_SUCCESS to indicate that device open is successful or an error code for error

**ERROR CODE**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>KVS_ERR_DEV_NOT_EXIST</td>
<td>the device does not exist</td>
</tr>
<tr>
<td>KVS_ERR_SYS_IO</td>
<td>communication with device failed</td>
</tr>
<tr>
<td>KVS_ERR_PARAM_INVALID</td>
<td>URI is NULL</td>
</tr>
</tbody>
</table>
6.2.2  

\[ \textit{kvs\_get\_device\_info}(kvs\_device\_handle \textit{dev\_hd}, \textit{kvs\_device *dev\_info}) \]

This function call retrieves the device information (e.g., kvs\_device data structure).

**PARAMETERS**

<table>
<thead>
<tr>
<th>IN</th>
<th>dev_hd</th>
<th>device handle</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUT</td>
<td>dev_info</td>
<td>kvs_device data structure (device information)</td>
</tr>
</tbody>
</table>

**ERROR CODE**

- KVS\_ERR\_DEV\_NOT\_EXIST: no device exists for the device handle
- KVS\_ERR\_SYS\_IO: communication with device failed
6.2.3  kvs_close_device

\textit{kvs\_result} \textit{kvs\_close\_device} \textit{(kvs\_device\_handle dev\_hd)}

This API closes a KVS device. \textit{dev\_hd} is associated with an open device.

PARAMETERS
IN dev\_hd  device handle

ERROR CODE
KVS\_ERR\_DEV\_NOT\_EXIST  no device with the \textit{dev\_hd} exists
KVS\_ERR\_SYS\_IO  communication with device failed
6.2.4  kvs_get_device_capacity

kvs_result kvs_get_device_capacity(kvs_device_handle dev_hd, uint64_t *dev_capacity)

This function call returns device capacity in bytes referenced by the given device handle.

PARAMETERS
IN  dev_hd    device handle
OUT  dev_capacity  device capacity

RETURNS
KVS_SUCCESS for successful completion or an error code for error

ERROR CODE
KVS_Err_DEV_NOT_EXIST   no device exists for the device handle
KVS_Err_SYS_IO          communication with device failed
6.2.5   \textit{kvs\_get\_device\_utilization} \hfill

\textit{kvs\_result kvs\_get\_device\_utilization (kvs\_device\_handle dev\_hd, uint32\_t \*dev\_utilization)}

This function call returns the device utilization (i.e, used ratio of the device) by the given device handle. The utilization is from 0(0.00\% utilized) to 10000(100\%).

\textbf{PARAMETERS}

\begin{tabular}{ll}
   \textbf{IN} & dev\_hd & device handle \\
   \textbf{OUT} & dev\_utilization & device utilization \\
\end{tabular}

\textbf{RETURNS}

KVS\_SUCCESS for successful completion or an error code for error

\textbf{ERROR CODE}

\begin{tabular}{ll}
   KVS\_ERR\_DEV\_NOT\_EXIST & no device exists for the device handle \\
   KVS\_ERR\_SYS\_IO & communication with device failed \\
\end{tabular}
6.2.6  \textit{kvs\_get\_min\_key\_length}

\textit{kvs\_result kvs\_get\_min\_key\_length (kvs\_device\_handle dev\_hd, uint32\_t *min\_key\_length)}

This function call returns the minimum length of key that the device supports.

\textbf{PARAMETERS}

\begin{itemize}
  \item \textbf{IN}  \textbf{dev\_hd}  \hspace{1cm} device handle
  \item \textbf{OUT}  \textbf{min\_key\_length}  \hspace{1cm} minimum key length that the device supports
\end{itemize}

\textbf{RETURNS}

KVS\_SUCCESS for successful completion or an error code for error

\textbf{ERROR CODE}

\begin{itemize}
  \item KVS\_ERR\_DEV\_NOT\_EXIST  \hspace{1cm} no device exists for the device handle
  \item KVS\_ERR\_SYS\_IO  \hspace{1cm} communication with device failed
\end{itemize}
6.2.7  \textit{kvs\_get\_max\_key\_length}

\texttt{kvs\_result kvs\_get\_max\_key\_length (kvs\_device\_handle dev\_hd, uint32\_t *max\_key\_length)}

This function call returns the maximum length of key that the device supports.

\textbf{PARAMETERS}
\begin{itemize}
  \item \textbf{IN}  dev\_hd \hspace{2cm} device handle
  \item \textbf{OUT} max\_key\_length \hspace{2cm} maximum key length that the device support
\end{itemize}

\textbf{RETURNS}
KVS\_SUCCESS for successful completion or an error code for error

\textbf{ERROR CODE}
\begin{itemize}
  \item KVS\_ERR\_DEV\_NOT\_EXIST \hspace{2cm} no device exists for the device handle
  \item KVS\_ERR\_SYS\_IO \hspace{2cm} communication with device failed
6.2.8  \textit{kvs\_get\_min\_value\_length}

\texttt{kvs\_result kvs\_get\_min\_value\_length (kvs\_device\_handle dev\_hd, uint32\_t *min\_value\_length)}

This function call returns the minimum length of value that the device supports.

\begin{description}
\item[PARAMETERS]
\item[IN] dev\_hd \hspace{1cm} device handle \\
\item[OUT] min\_value\_length \hspace{1cm} minimum value length that the device supports
\end{description}

\begin{description}
\item[RETURNS]
KVS\_SUCCESS for successful completion or an error code for error
\end{description}

\begin{description}
\item[ERROR CODE]
\texttt{KVS\_ERR\_DEV\_NOT\_EXIST} \hspace{1cm} no device exists for the device handle \\
\texttt{KVS\_ERR\_SYS\_IO} \hspace{1cm} communication with device failed
\end{description}
6.2.9  \texttt{kvs\_get\_max\_value\_length}

\texttt{kvs\_result kvs\_get\_max\_value\_length (kvs\_device\_handle dev\_hd, uint32\_t \^{}max\_value\_length)}

This function call returns the maximum length of value that the device supports.

\textbf{PARAMETERS}
\begin{itemize}
  \item \texttt{IN dev\_hd} device handle
  \item \texttt{OUT max\_value\_length} maximum value length that the device supports
\end{itemize}

\textbf{RETURNS}
\begin{itemize}
  \item \texttt{KVS\_SUCCESS} for successful completion or an error code for error
\end{itemize}

\textbf{ERROR CODE}
\begin{itemize}
  \item \texttt{KVS\_ERR\_DEV\_NOT\_EXIST} no device exists for the device handle
  \item \texttt{KVS\_ERR\_SYS\_IO} communication with device failed
6.2.10 \texttt{kvs\_get\_optimal\_value\_length}

\texttt{kvs\_result kvs\_get\_optimal\_value\_length (kvs\_device\_handle dev\_hd, uint32\_t \star opt\_value\_length)}

This function call returns the optimal length of value that the device supports. The device will perform best when the value size is the same as the optimal value size.

\textbf{PARAMETERS}

\begin{itemize}
  \item \textbf{IN} \hspace{0.5cm} \texttt{dev\_hd} \hspace{0.5cm} device handle
  \item \textbf{OUT} \hspace{0.5cm} \texttt{opt\_value\_length} \hspace{0.5cm} optimal value length that the device supports
\end{itemize}

\textbf{RETURNS}

KVS\_SUCCESS for successful completion or an error code for error

\textbf{ERROR CODE}

\begin{itemize}
  \item KVS\_ERR\_DEV\_NOT\_EXIST \hspace{0.5cm} no device exists for the device handle
  \item KVS\_ERR\_SYS\_IO \hspace{0.5cm} communication with device failed
\end{itemize}
6.2.11 kvs_create_key_space

kvs_result kvs_create_key_space (kvs_device_handle dev_hd, kvs_key_space_name *key_space_name, uint64_t size, kvs_option_key_space opt)

This API creates a new Key Space in a device. An application needs to specify a unique Key Space name, and its capacity. The capacity is defined in bytes. A 0 (numeric zero) capacity means no limitation where device capacity limits actual Key Space capacity. The device assigns a unique id while an application assigns a unique name.

PARAMETERS
IN  dev_hd  device handle
IN  key_space_name  name of Key Space
IN  size  capacity of a Key Space with respect to key value pair size (key size + value size) in bytes
IN  opt             Key Space option

RETURNS
KVS_SUCCESS if a Key Space is created successfully or an error code for error.

ERROR CODE
KVS_ERR_DEV_CAPACITY  the Key Space size is too big
KVS_ERR_KS_EXIST      Key Space with the same name already exists
KVS_ERR_KS_NAME       Key Space name does not meet the requirement (e.g., too long (see 5.2.2))
KVS_ERR_DEV_NOT_EXIST no device with the dev_hd exists
KVS_ERR_SYS_IO        communication with device failed
KVS_ERR_PARAM_INVALID name or opt is NULL
KVS_ERR_OPTION_INVALID Key Space option is not supported
6.2.12 kvs_delete_key_space

```c
kvs_result kvs_delete_key_space (kvs_device_handle dev_hd,
    kvs_key_space_name *key_space_name)
```

This API deletes a Key Space identified by the given Key Space name. It deletes all Key Value Pairs within the Key Space as well as the Key Space itself. As a side effect of the delete operation, the Key Space is closed for all applications as the Key Space is no longer present in the device. It is recommended that all applications accessing a Key Space close the Key Space prior to deleting the Key Space.

**PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN dev_hd</td>
<td>device handle</td>
</tr>
<tr>
<td>IN key_space_name</td>
<td>Key Space name</td>
</tr>
</tbody>
</table>

**RETURNS**

- KVS_SUCCESS if a Key Space is deleted successfully or an error code for error

**ERROR CODE**

- KVS_ERR_KS_NOT_EXIST: Key Space with a given `key_space_name` does not exist
- KVS_ERR_DEV_NOT_EXIST: no device with the `dev_hd` exists
- KVS_ERR_SYS_IO: communication with device failed
6.2.13 kvs_list_key_spaces

kvs_result kvs_list_key_spaces (kvs_device_handle dev_hd, uint32_t index, uint32_t buffer_size, kvs_key_space_name *names, uint32_t *ks_cnt)

For a KVS device, this API returns the names of Key Spaces up to the number that fit in the buffer specified in buffer_size. A device may define a unique order of Key Space names and index is defined relative to that order. The value of index may change if a Key Space is created or deleted. The index specifies a start list entry offset, buffer_size specifies the size of the kvs_key_space_name array, and names is a buffer to store name information. The ks_cnt specifies the number of Key Space names to return.

PARAMETERS
IN dev_hd           device handle
IN index            start index of Key Space as an input
IN buffer_size      buffer size of Key Space names
OUT names           buffer to store Key Space names. This buffer is required to be preallocated before calling this routine.
OUT ks_cnt          the number of names stored in the buffer

RETURNS
KVS_SUCCESS if the operation is successful or an error code for error.

ERROR CODE
KVS_ERR_KS_NOT_EXIST       no Key Space exists
KVS_ERR_DEV_NOT_EXIST      no device with the dev_hd exists
KVS_ERR_SYS_IO             communication with device failed
KVS_ERR_KS_INDEX           index is not valid
KVS_ERR_PARAM_INVALID      names or ks_cnt is NULL
6.3 Key Space-level APIs

6.3.1 kvs_open_key_space

\texttt{kvs_result kvs_open_key_space (kvs_device_handle dev_hd, char *name, kvs_key_space_handle *ks_hd)}

This API opens a Key Space with a given name. This API communicates with a device to initialize the corresponding Key Space. The device is capable of recognizing and initializing the Key Space. If the Key Space is already open, this API returns \texttt{KVS\_ERR\_KS\_OPEN}.

\textbf{PARAMETERS}

\begin{itemize}
  \item \texttt{IN dev_hd} Device handle
  \item \texttt{IN name} Key Space name
  \item \texttt{OUT ks_hd} Key Space handle
\end{itemize}

\textbf{RETURNS}

\begin{itemize}
  \item \texttt{KVS\_SUCCESS} to indicate that device open is successful or an error code for error
\end{itemize}

\textbf{ERROR CODE}

\begin{itemize}
  \item \texttt{KVS\_ERR\_KS\_NOT\_EXIST} Key Space with the given \textit{name} does not exist,
  \item \texttt{KVS\_ERR\_DEV\_NOT\_EXIST} No device with \textit{dev_hd} exists
  \item \texttt{KVS\_ERR\_SYS\_IO} Communication with device failed
  \item \texttt{KVS\_ERR\_KS\_OPEN} Key Space has been opened already
\end{itemize}
6.3.2 kvs_close_key_space

**kvs_result kvs_close_key_space (kvs_key_space_handle ks_hd)**

This API closes a Key Space with a given Key Space handle. This API communicates with the device to close the corresponding Key Space. This API may clean up any internal Key Space states in the device. If the given Key Space was not open, this returns a KVS_ERR_KS_NOT_OPEN error.

**PARAMETERS**

IN ks_hd Key Space handle

**RETURNS**

KVS_SUCCESS to indicate that closing a Key Space is successful or an error code for an error

**ERROR CODE**

KVS_ERR_KS_NOT_OPEN Key space is not open
KVS_ERR_KS_NOT_EXIST Key Space with a given ks_hd does not exist
KVS_ERR_DEV_NOT_EXIST No device with dev_hd exists
KVS_ERR_SYS_IO Communication with device failed
6.3.3  

\texttt{kvs\_get\_key\_space\_info}

\texttt{kvs\_result \textit{kvs\_get\_key\_space\_info} (kvs\_key\_space\_handle \textit{ks\_hd}, kvs\_key\_space *\textit{ks})}

This API retrieves Key Space information.

\textbf{PARAMETERS}

IN \textit{ks\_hd}  Key Space handle

OUT \textit{ks}  Key Space information

\textbf{RETURNS}

\textbf{KVS\_SUCCESS} to indicate that getting Key Space info is successful or an error code for error.

\textbf{ERROR CODE}

\begin{itemize}
  \item \texttt{KVS\_ERR\_KS\_NOT\_EXIST}  Key Space with a given \textit{ks\_hd} does not exist
  \item \texttt{KVS\_ERR\_SYS\_IO}  Communication with device failed
  \item \texttt{KVS\_ERR\_PARAM\_INVALID}  \textit{ks} is NULL
\end{itemize}
6.3.4  `kvs_get_kvp_info`

```c
kvs_result kvs_get_kvp_info (kvs_key_space_handle ks_hd, kvs_key *key, kvs_kvp_info *info)
```

This API retrieves key value pair properties. Key value pair properties includes a key length, a key byte stream, and a value length. Please refer to section 5.4.22 `kvs_kvp_info` for details. This API is intended to be used when a buffer length for a value is not known. The caller should create `kvs_kvp_info` object before calling this API.

**PARAMETERS**

- **IN ks_hd**  Key Space handle
- **IN key**  Key to find for key value properties
- **OUT info**  Key value pair properties

**RETURNS**

- **KVS_SUCCESS** to indicate that retrieving key value pair properties is successful or an error code for error.

**ERROR CODE**

- KVS_ERR_KS_NOT_EXIST  Key Space with a given `ks_hd` does not exist
- KVS_ERR_SYS_IO  Communication with device failed
- KVS_ERR_KEY_LENGTH_INVALID  given `key` is not supported (e.g., length)
- KVS_ERR_PARAM_INVALID  `key` or `info` is NULL
- KVS_ERR_KEY_NOT_EXIST  `key` does not exist
6.3.5  kvs_retrieve_kvp

kvs_result kvs_retrieve_kvp (kvs_key_space_handle ks_hd,  kvs_key *key,
                          kvs_option_retrieve *opt, kvs_value *value)

This API retrieves a key value pair value with the given key. The value parameter contains output buffer information for the value. As an input, value.value contains the buffer to store the key value pair value and value.length contains the buffer size. The key value pair value is copied to value.value buffer and value.length is set to the retrieved value size. If the offset of value is not zero, the value of key value pair is copied into the buffer, skipping the first offset bytes of the value of key value pair. The offset is required to align to KVS_ALIGNMENT_UNIT. If the offset is not aligned, a KVS_ERR_VALUE_OFFSET_MISALIGNED error is returned and no data is transferred. If an allocated value buffer is not big enough to hold the value, the device will set actual_value_size to the size of the value, return KVS_ERR_BUFFER_SMALL and data is returned to the buffer up to the size specified in value.length.

The retrieve option is defined in 5.4.8 kvs_option_retrieve.

PARAMETERS
IN ks_hd  Key Space handle
IN key  Key of the key value pair to get value
IN opt  retrieval option. It may be NULL. In that case, the default retrieval option is used.
OUT value  value to receive the key value pair's value from device

RETURNS
KVS_SUCCESS to indicate that retrieve is successful or an error code for error.

ERROR CODE
KVS_ERR_VALUE_OFFSET_MISALIGNED  kvs_value.offset is not aligned to KVS_ALIGNMENT_UNIT
KVS_ERR_KS_NOT_EXIST  Key Space with a given ks_hd does not exist
KVS_ERR_SYS_IO  Communication with device failed
KVS_ERR_KEY_LENGTH_INVALID  given key is not supported (e.g., length)
KVS_ERR_BUFFER_SMALL  Buffer space of value is not allocated or not enough
KVS_ERR_PARAM_INVALID  key or value is NULL
KVS_ERR_OFFSET_INVALID  kvs_value.offset is invalid
KVS_ERR_OPTION_INVALID  the option is not supported
KVS_ERR_KEY_NOT_EXIST  Key does not exist
6.3.6 \textit{kvs\_retrieve\_kvp\_async}

\textbf{\textit{kvs\_result kvs\_retrieve\_kvp\_async}} (\textit{kvs\_key\_space\_handle ks\_hd, kvs\_key \*key, kvs\_option\_retrieve \*opt, void \*private1, void \*private2, kvs\_value \*value, kvs\_postprocess\_function post\_fn})

This API asynchronously retrieves a key value pair value with the given key and returns immediately regardless of whether the pair is actually retrieved from a device or not. The final execution results are returned to post process function through \textit{kvs\_postprocess\_context}. The value parameter contains output buffer information for the value. As an input \textit{value.value} contains the buffer to store the key value pair value and \textit{value.length} contains the buffer size. The key value pair value is copied to \textit{value.value} buffer and \textit{value.length} is set to the retrieved value size. If the offset of value is not zero, the value of key value pair is copied into the buffer, skipping the first offset bytes of the value of key value pair. That is, \textit{value.length} is equal to the total size of (actual\_value\_size – offset). The offset is required to align to \textit{KVS\_ALIGNMENT\_UNIT}. If the offset is not aligned, a \textit{KVS\_ERR\_VALUE\_OFFSET\_MISALIGNED} error is returned. If an allocated value buffer is not big enough to hold the value, it will set \textit{value.actual\_value\_size} to the actual value length and return \textit{KVS\_ERR\_BUFFER\_SMALL}.

The retrieve option of the retrieve operation is defined in 5.4.8\textit{kvs\_option\_retrieve}.

\textbf{PARAMETERS}

\begin{itemize}
    \item \textbf{IN} \textit{ks\_hd} : Key Space handle
    \item \textbf{IN} \textit{key} : Key of the key value pair to get value
    \item \textbf{IN} \textit{opt} : retrieval option. It may be NULL. In that case, the default retrieval option is used.
    \item \textbf{IN} \textit{private1} : Structure passed that may be returned in the \textit{kvs\_postprocess\_context} after the async IO is completed
    \item \textbf{IN} \textit{private2} : Structure passed that may be returned in the \textit{kvs\_postprocess\_context} after the async IO is completed
    \item \textbf{OUT} \textit{value} : value to receive the key value pair's value from device
    \item \textbf{IN} \textit{post\_fn} : post process function pointer
\end{itemize}

\textbf{RETURNS}

\texttt{KVS\_SUCCESS} to indicate that retrieve is successful or an error code for error.

\textbf{ERROR CODE}

- \texttt{KVS\_ERR\_VALUE\_OFFSET\_MISALIGNED} : \textit{kvs\_value.offset} is not aligned to \textit{KVS\_ALIGNMENT\_UNIT}
- \texttt{KVS\_ERR\_KS\_NOT\_EXIST} : Key Space with a given \textit{ks\_hd} does not exist
- \texttt{KVS\_ERR\_SYS\_IO} : Communication with device failed
- \texttt{KVS\_ERR\_KEY\_LENGTH\_INVALID} : given \textit{key} is not supported (e.g., length)
- \texttt{KVS\_ERR\_BUFFER\_SMALL} : Buffer space of \textit{value} is not allocated or not enough
- \texttt{KVS\_ERR\_PARAM\_INVALID} : \textit{key} or \textit{value} is NULL
KVS_ERR_OFFSET_INVALID  \hspace{1cm} kvs_value.offset is invalid
KVS_ERR_OPTION_INVALID  \hspace{1cm} the option is not supported
KVS_ERR_KEY_NOT_EXIST  \hspace{1cm} Key does not exist
6.3.7  kvs_store_kvp

\[ \text{kvs_result kvs_store_kvp (kvs_key_space_handle ks_hd, kvs_key *key, kvs_value *value, kvs_option_store *opt)} \]

This API writes a Key-value key value pair into a Key Space. This API supports the modes defined in section 5.4.9 as specified in opt.

Store operations execute based on the existence of the key and the kvs_option_store specified. If the Key Space does not have enough space to store a key value pair, a KVS_ERR_KS_CAPACITY error message is returned.

PARAMETERS

\begin{itemize}
  \item IN ks_hd Key Space handle
  \item IN key Key of the key value pair to store into Key Space
  \item IN value Value of the key value pair to store into Key Space
  \item IN opt Store option. It may be NULL. In that case, the kvs_store_type of \textit{KVS_STORE_POST} (see 5.4.9) is used.
\end{itemize}

RETURNS

\begin{itemize}
  \item KVS_SUCCESS to indicate that store is successful or an error code for error.
\end{itemize}

ERROR CODE

\begin{itemize}
  \item KVS_ERR_VALUE_OFFSET_MISALIGNED \hspace{1cm} kvs_value.offset is not aligned to KVS_ALIGNMENT_UNIT
  \item KVS_ERR_KS_NOT_EXIST Key Space with a given \textit{ks_hd} does not exist
  \item KVS_ERR_SYS_IO Communication with device failed
  \item KVS_ERR_KEY_LENGTH_INVALID given \textit{key} is not supported (e.g., length)
  \item KVS_ERR_PARAM_INVALID a \textit{key} or a \textit{value} is NULL
  \item KVS_ERR_OFFSET_INVALID \hspace{1cm} kvs_value.offset is invalid
  \item KVS_ERR_OPTION_INVALID unsupported option
  \item KVS_ERR_KS_CAPACITY Key Space does not have enough space to store this key value pair
  \item KVS_ERR_VALUE_UPDATE_NOT_ALLOWED a key exists but overwrite is not permitted
  \item KVS_ERR_VALUE_LENGTH_INVALID given value is not supported (e.g., length)
\end{itemize}
6.3.8 kvs_store_kvp_async

kvs_result kvs_store_kvp_async (kvs_key_space_handle ks_hd, kvs_key *key, kvs_value *value, kvs_option_store *opt, kvs_postprocess_function post_fn, void *private1, void *private2)

This API asynchronously writes a Key-value key value pair into a Key Space and returns immediately regardless of whether the pair is actually written to a device or not. The final execution results are returned to post process function through kvs_postprocess_context. This API supports the modes defined in section 5.4.9.

Store operations execute based on the existence of the key and the kvs_option_store specified. If the Key Space does not have enough space to store a key value pair, a KVS_ERR_KS_CAPACITY error message is returned.

PARAMETERS
IN ks_hd Key Space handle
IN key Key of the key value pair to store into Key Space
IN value Value of the key value pair to store into Key Space
IN opt Store option. It may be NULL. In that case, the kvs_store_type of KVS_STORE_POST (see 5.4.9) is used.
IN post_fn post process function pointer
IN private1 Structure passed that may be returned in the kvs_postprocess_context after the async IO is completed
IN private2 Structure passed that may be returned in the kvs_postprocess_context after the async IO is completed

RETURNS
KVS_SUCCESS to indicate that store is successful or an error code for error.

ERROR CODE
KVS_ERR_VALUE_OFFSET_MISALIGNED kvs_value.offset is not aligned to KVS_ALIGNMENT_UNIT
KVS_ERR_KS_NOT_EXIST Key Space with a given ks_hd does not exist
KVS_ERR_SYS_IO Communication with device failed
KVS_ERR_KEY_LENGTH_INVALID given key is not supported (e.g., length)
KVS_ERR_PARAM_INVALID a key or a value is NULL
KVS_ERR_OPTION_INVALID unsupported option
KVS_ERR_KS_CAPACITY Key Space or device does not have enough space to store this key value pair
KVS_ERR_VALUE_UPDATE_NOT_ALLOWED a key exists but overwrite is not permitted
KVS_ERR_VALUE_LENGTH_INVALID given value is not supported (e.g., length)
6.3.9  kvs_delete_kvp

kvs_result kvs_delete_kvp (kvs_key_space_handle ks_hd, kvs_key* key, kvs_option_delete *opt)

This API deletes key value pair(s) with a given key.

PARAMETERS
IN ks_hd  Key Space handle
IN key    Key of the key value pair(s) to delete
IN opt    delete option

RETURNS
KVS_SUCCESS      Indicate that delete is successful or an error code for error.

ERROR CODE
KVS_ERR_KS_NOT_EXIST       Key Space with a given ks_hd does not exist
KVS_ERR_PARAM_INVALID      key is NULL.
KVS_ERR_SYS_IO             Communication with device failed
KVS_ERR_KEY_LENGTH_INVALID given key is not supported (e.g., length)
KVS_ERR_KEY_NOT_EXIST      key does not exist
6.3.10 \textit{kvs\_delete\_kvp\_async}

\begin{verbatim}

\texttt{kvs\_result kvs\_delete\_kvp\_async (kvs\_key\_space\_handle ks\_hd, kvs\_key* key,
 kvs\_option\_delete *opt, kvs\_postprocess\_function *post\_fn, void *private1, void
 *private2)}

\end{verbatim}

This API asynchronously deletes key value pair(s) with a given key and returns
immediately regardless of whether the pair is actually deleted from a device or not. The
final execution results are returned to post process function through
\texttt{kvs\_postprocess\_context}.

\section*{PARAMETERS}

\begin{itemize}
\item \texttt{IN ks\_hd} \hspace{1em} Key Space handle
\item \texttt{IN key} \hspace{1em} Key of the key value pair(s) to delete
\item \texttt{IN opt} \hspace{1em} delete option
\item \texttt{IN post\_fn} \hspace{1em} post process function pointer
\item \texttt{IN private1} \hspace{1em} Structure passed that may be returned in the \texttt{kvs\_postprocess\_context} after the async IO is completed
\item \texttt{IN private2} \hspace{1em} Structure passed that may be returned in the \texttt{kvs\_postprocess\_context} after the async IO is completed
\end{itemize}

\section*{RETURNS}

\begin{itemize}
\item \texttt{KVS\_SUCCESS} \hspace{1em} Indicate that delete is successful or an error code for error.
\end{itemize}

\section*{ERROR CODE}

\begin{itemize}
\item \texttt{KVS\_ERR\_KS\_NOT\_EXIST} \hspace{1em} Key Space with a given \texttt{ks\_hd} does not exist
\item \texttt{KVS\_ERR\_PARAM\_INVALID} \hspace{1em} \texttt{key} is NULL.
\item \texttt{KVS\_ERR\_SYS\_IO} \hspace{1em} Communication with device failed
\item \texttt{KVS\_ERR\_KEY\_LENGTH\_INVALID} \hspace{1em} given \texttt{key} is not supported (e.g., length)
\item \texttt{KVS\_ERR\_KEY\_NOT\_EXIST} \hspace{1em} \texttt{key} does not exist
\end{itemize}
6.3.11 \texttt{kvs\_delete\_key\_group}

\texttt{kvs\_result kvs\_delete\_key\_group(kvs\_key\_space\_handle \textit{ks\_hd},
\text{\textit{kvs\_key\_group\_filter} \texttt{*grp\_fltr});
}

This function call deletes the key-value pairs in a Key Space that matches with \textit{grp\_fltr}.

\textbf{PARAMETERS}

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{ks_hd}</td>
<td>Key Space handle</td>
</tr>
<tr>
<td>\textit{grp_fltr}</td>
<td>Key group filter to delete</td>
</tr>
</tbody>
</table>

\textbf{RETURNS}

\texttt{KV\_SUCCESS} to indicate that delete key group is successful or an error code for error.

\textbf{ERROR CODE}

<table>
<thead>
<tr>
<th>Error Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{KVS_ERR_KS_NOT_EXIST}</td>
<td>Key Space with a given \textit{ks_hd} does not exist</td>
</tr>
<tr>
<td>\texttt{KVS_ERR_PARAM_INVALID}</td>
<td>\textit{grp_fltr} is NULL.</td>
</tr>
<tr>
<td>\texttt{KVS_ERR_SYS_IO}</td>
<td>Communication with device failed</td>
</tr>
</tbody>
</table>
6.3.12 kvs_delete_key_group_async

kvs_result kvs_delete_key_group_async(kvs_key_space_handle ks_hd,
kvs_key_group_filter *grp_fltr, kvs_postprocess_function post_fn, void *
private1, void *private2);

This function call deletes the key-value pairs in a Key Space that matches with grp_fltr and returns immediately regardless of whether a key group is actually deleted from a device or not. The final execution results are returned to post process function through kvs_postprocess_context.

PARAMETERS
IN ks_hd    Key Space handle
IN grp_fltr key group filter to delete
IN post_fn  post process function pointer
IN private1 Structure passed that may be returned in the kvs_postprocess_context after the async IO is completed
IN private2 Structure passed that may be returned in the kvs_postprocess_context after the async IO is completed

RETURNS
KV_SUCCESS to indicate that delete key group is successful or an error code for error.

ERROR CODE
KVS_ERR_KS_NOT_EXIST    Key Space with a given ks_hd does not exist
KVS_ERR_PARAM_INVALID   grp_fltr is NULL.
KVS_ERR_SYS_IO          Communication with device failed
6.3.13 kvs_exist_kv_pairs

kvs_result kvs_exist_kv_pairs (kvs_key_space_handle ks_hd, uint32_t key_cnt, kvs_key *keys, uint32_t buffer_size, kvs_exist_list *list)

This API checks if a set of one or more keys exists and returns a bool type status. The existence of a key value pair is determined during an implementation-dependent time window while this API executes. Therefore, repeated routine calls may return different outputs in multi-threaded environments. One bit is used for each key. Therefore when 32 keys are intended to be checked, a caller should allocate 32 bits (i.e., 4 bytes) of memory buffer and the existence information is filled. The LSB (Least Significant Bit) of the list->result_buffer indicates if the first key exist or not.

PARAMETERS
IN ks_hd    Key Space handle
IN key_cnt  the number of keys to check
IN keys     a set of keys to check
IN buffer_size list buffer size in bytes
OUT list    a kvs_exist_list indicates whether corresponding key(s) exists or not

RETURNS
KVS_SUCCESS to indicate success or an error code for error.

ERROR CODE
KVS_ERR_KS_NOT_EXIST    Key Space with a given ks_hd does not exist
KVS_ERR_BUFFER_SMALL    the buffer space of list->result_buffer is not big enough
KVS_ERR_PARAM_INVALID   keys or list parameter is NULL
KVS_ERR_SYS_IO          Communication with device failed
6.3.14 kvs_exist_kv_pairs_async

\[
kvs\_result\ kvs\_exist\_kv\_pairs\_async(kvs\_key\_space\_handle\ k_s\_hd, \ uint32\_t\ key\_cnt,\ kvs\_key* keys, \ uint32\_t\ buffer\_size, \ kvs\_exist\_list* list, \ void* \private1, \\
void* \private2, \ kvs\_postprocess\_function \post_fn)
\]

This API asynchronously checks if a set of keys exists and returns a bool type status. It returns immediately regardless of whether keys are checked from a device or not. The final execution results are returned to the post process function through kvs_postprocess_context. The existence of a key value pair is determined during an implementation-dependent time window while this API executes. Therefore, repeated routine calls is able to return different outputs in multi-threaded environments. One bit is used for each key. Therefore when 32 keys are intended to be checked, a caller shall allocate 32 bits (i.e., 4 bytes) of memory buffer and the existence information is filled. The LSB (Least Significant Bit) of the list->result_buffer indicates if the first key exist or not.

PARAMETERS
IN ks_hd Key Space handle
IN key_cnt the number of keys
IN keys a set of keys to check
IN buffer_size list buffer size in bytes
IN private1 Structure passed that may be returned in the kvs_postprocess_context after the async IO is completed
IN private2 Structure passed that may be returned in the kvs_postprocess_context after the async IO is completed
OUT list a list indicates whether a corresponding key exists or not
IN post_fn post process function pointer

RETURNS
KVS_SUCCESS to indicate success or an error code for error.

ERROR CODE
KVS_ERR_KS_NOT_EXIST Key Space with a given ks_hd does not exist
KVS_ERR_PARAM_INVALID keys or list parameter is NULL
KVS_ERR_BUFFER_SMALL the buffer space of list->result_buffer is not big enough
KVS_ERR_SYS_IO Communication with device failed
6.4 Iterator Function calls

6.4.1 kvs_create_iterator

This function call enables applications to set up a Key Group such that the keys in that Key Group may be iterated within a Key Space (i.e., kvs_create_iterator()) enables a device to prepare a Key Group of keys for iteration by matching a given bit pattern (it_fltr.bit_pattern) to all keys in the Key Space considering bits indicated by it_fltr.bitmask and the device sets up a Key Group of keys matching that “(bitmask & key) == bit_pattern.” (e.g., if the bitmask and bit_pattern are 0xF0000000 and 0x30000000 respectively, then kvs_create_iterator() will prepare a subset of keys which has 0x3XXXXXXX in keys.

Below are some examples of Key Groups.

1) If applications want to get all the existing keys within the device with the first bit of a key set to 1, kvs_create_iterator() should be called with bitmask = 0x80000000 (1000 0000 0000 0000 0000 0000 0000 0000) and bit_pattern = 0x80000000 (1000 0000 0000 0000 0000 0000 0000 0000).

2) If applications want to get all the existing keys within the device with the first bit of key set to 0, bitmask should be 0x80000000 (1000 0000 0000 0000 0000 0000 0000 0000) and bit_pattern should be 0x0 (0000 0000 0000 0000 0000 0000 0000 0000).

3) If applications want to get all the existing keys with the second and third bytes (bit 8 ~ bit15) equal to 0x04, bitmask should be 0x00FF0000 (0000 0000 1111 1111 0000 0000 0000 0000) and bit_pattern should be 0x00040000 (0000 0000 0000 0100 0000 0000 0000 0000).

4) If application wants to get all the existing keys with bit 1 ~ bit 4 equal to (0101), bitmask should be 0x78000000 (0111 1000 0000 0000 0000 0000 0000 0000) and bit_pattern should be 0x28000000 (0010 1000 0000 0000 0000 0000 0000 0000).

It also sets up the iterator option; kvs_iterator_next() will only retrieve keys when the kvs_option_iterator is KVS_ITERATOR_OPT_KEY while kvs_iterator_next() will retrieve key and value pairs when the kvs_option_iterator is KVS_ITERATOR_OPT_KV. An iterator handle is provided as an output of this function call.

PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN</td>
<td>ks_hd</td>
</tr>
<tr>
<td>IN</td>
<td>iter_op</td>
</tr>
<tr>
<td>IN</td>
<td>iter_fltr</td>
</tr>
<tr>
<td>OUT</td>
<td>iter_hd</td>
</tr>
</tbody>
</table>

RETURNS
KVS_SUCCESS to indicate that device open is successful or an error code for error.

**ERROR CODE**

- **KVS_ERR_KS_NOT_EXIST**  
  Key Space with a given *ks_hd* does not exist

- **KVS_ERR_PARAM_INVALID**  
  *it_fltr* is NULL.

- **KVS_ERR_SYS_IO**  
  Communication with device failed

- **KVS_ERR_ITERATOR_MAX**  
  the maximum number of iterators that a device supports is already open. No more iterator are able to be opened.

- **KVS_ERR_ITERATOR_OPEN**  
  *iterator is already opened*

- **KVS_ERR_OPTION_INVALID**  
  the device does not support the specified iterator options

- **KVS_ERR_ITERATOR_FILTER_INVALID**  
  iterator filter(match bitmask and pattern) is not valid
6.4.2  

**kvs_delete_iterator**

`kvs_result kvs_delete_iterator(kvs_key_space_handle ks_hd, kvs_iterator_handle iter_hd)`

This function call releases the resources for the iterator Key Group specified by `iter_hd` in the specified Key Space.

**PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN ks_hd</td>
<td>Key Space handle</td>
</tr>
<tr>
<td>IN iter_hd</td>
<td>iterator handle</td>
</tr>
</tbody>
</table>

**ERROR CODE**

- **KVS_ERR_KS_NOT_EXIST**  Key Space with a given `ks_hd` does not exist
- **KVS_ERR_SYS_IO**        Communication with device failed
- **KVS_ERR_ITERATOR_NOT_EXIST**  the iterator Key Group does not exist
6.4.3 \textit{kvs\_iterate\_next}

\texttt{kvs\_result kvs\_iterate\_next(kvs\_key\_space\_handle ks\_hd, kvs\_iterator\_handle iter\_hd, uint32\_t buffer\_size, kvs\_iterator\_list *iter\_list);}\

This function call obtains a subset of key or key-value pairs from an Key Group of \texttt{iter\_hd} within a Key Space (i.e., \textit{kvs\_iterator\_next()} retrieves the next Key Group of keys or key-value pairs in the iterator Key Group (\texttt{iter\_hd}) that is created with \textit{kvs\_create\_iterator()} command). \texttt{buffer\_size} is the iterator buffer (\texttt{iter\_list}) size in bytes. The retrieved values (\texttt{iter\_list}) are either keys or key-value pairs based on the iterator option which is specified by \textit{kvs\_create\_iterator()}.

After \textit{kvs\_create\_iterator} for a Key Group completes successfully, if a \textit{kvs\_store()} or \textit{kvs\_delete()} command with a key that matches that Key Group is received, then the keys associated with that command may or may not be included in that iterator.

In the output of this operation, \texttt{iter\_list.num\_entries} provides number of iterator elements in \texttt{iter\_list.it\_list} and \texttt{iter\_list.end} indicates if there are more elements in the iterator Key Group after this operation. If \texttt{iter\_list.end} is zero, there are more iterator Key Group elements and the host may run \textit{kvs\_iterator\_next()} again to retrieve those elements. If \texttt{iter\_list.end} is one, there are no more iterator Key Group elements and that iterator has reached the last element in the Key Group.

Output values (\texttt{iter\_list.it\_list}) are determined by the iterator option specified by an application.

- \textbf{KV\_ITERATOR\_OPT\_KEY [MANDATORY]}: a subset of keys are returned in \texttt{iter\_list.it\_list} data structure
- \textbf{KV\_ITERATOR\_OPT\_KEY\_VALUE}: a subset of key-value pairs are returned in \texttt{iter\_list.it\_list} data structure

**PARAMETERS**

- \textbf{IN ks\_hd} Key Space handle
- \textbf{IN iter\_hd} iterator handle
- \textbf{IN buffer\_size} iterator buffer (\texttt{iter\_list}) size in bytes
- \textbf{OUT iter\_list} output buffer for a set of keys or key-value pairs

**ERROR CODE**

- \texttt{KVS\_ERR\_KS\_NOT\_EXIST} Key Space with a given \texttt{ks\_hd} does not exist
- \texttt{KVS\_ERR\_PARAM\_INVALID} \texttt{iter\_list} parameter is NULL
- \texttt{KVS\_ERR\_SYS\_IO} Communication with device failed
- \texttt{KVS\_ERR\_ITERATOR\_NOT\_EXIST} the iterator Key Group does not exist
6.4.4 kvs_iterate_next_async

```c
kvs_result kvs_iterate_next_async(kvs_key_space_handle ks_hd, kvs_iterator_handle iter_hd, uint32_t buffer_size, void *private1, void *private2, kvs_iterator_list *iter_list, kvs_postprocess_function post_fn);
```

This function call obtains a subset of key or key-value pairs from an iterator Key Group of `iter_hd` within a Key Space (i.e., `kvs_iterator_next()`) retrieves a next Key Group of keys or key-value pairs in the iterator key group (`iter_hd`) that is set with `kvs_create_iterator()` command). `buffer_size` is the iterator buffer (`iter_list`) size in bytes. The retrieved values (`iter_list`) are either keys or key-value pairs based on the iterator option which is set by `kvs_create_iterator()`. It returns immediately regardless of whether the iterator list is ready from a device or not. The final execution results are returned to the post process function through `kvs_postprocess_context`.

When `kvs_store()` or `kvs_delete()` command whose key matches with an existing iterator Key Group is received, the keys may or may not be included in the iterator and the inclusion of the updated keys is unspecified.

In the output of this operation, `iter_list.num_entries` provides number of iterator elements in `iter_list.it_list` and `iter_list.end` indicates if there are more elements in the iterator Key Group after this operation. If `iter_list.end` is zero, there are more iterator Key Group elements and host may run `kvs_iterator_next()` again to retrieve those elements. If `iter_list.end` is one, there are no more iterator Key Group elements and the iterator reached the end.

Output values (`iter_list.it_list`) are determined by the iterator option set by an application.

- **KV_ITERATOR_OPT_KEY** [MANDATORY]: a subset of keys are returned in `iter_list.it_list` data structure
- **KV_ITERATOR_OPT_KEY_VALUE**: a subset of key-value pairs are returned in `iter_list.it_list` data structure

### PARAMETERS

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN</td>
<td>ks_hd</td>
<td>Key Space handle</td>
</tr>
<tr>
<td>IN</td>
<td>iter_hd</td>
<td>iterator handle</td>
</tr>
<tr>
<td>IN</td>
<td>buffer_size</td>
<td>iterator buffer (<code>iter_list</code>) size in bytes</td>
</tr>
<tr>
<td>IN</td>
<td>private1</td>
<td>Structure passed that may be returned in the <code>kvs_postprocess_context</code> after async IO is completed</td>
</tr>
<tr>
<td>IN</td>
<td>private2</td>
<td>Structure passed that may be returned in the <code>kvs_postprocess_context</code> after async IO is completed</td>
</tr>
<tr>
<td>OUT</td>
<td>iter_list</td>
<td>output buffer for a set of keys or key-value pairs</td>
</tr>
<tr>
<td>IN</td>
<td>post_fn</td>
<td>post process function pointer</td>
</tr>
<tr>
<td>ERROR CODE</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>KVS_ERR_KS_NOT_EXIST</td>
<td>Key Space with a given <em>ks_hd</em> does not exist</td>
<td></td>
</tr>
<tr>
<td>KVS_ERRgetParam_INVALID</td>
<td><em>iter_list</em> parameter is NULL</td>
<td></td>
</tr>
<tr>
<td>KVS_ERR_SYS_IO</td>
<td>Communication with device failed</td>
<td></td>
</tr>
<tr>
<td>KVS_ERR_ITERATOR_NOT_EXIST</td>
<td>the iterator Key Group does not exist</td>
<td></td>
</tr>
</tbody>
</table>