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# Tutorial on the DAOS API

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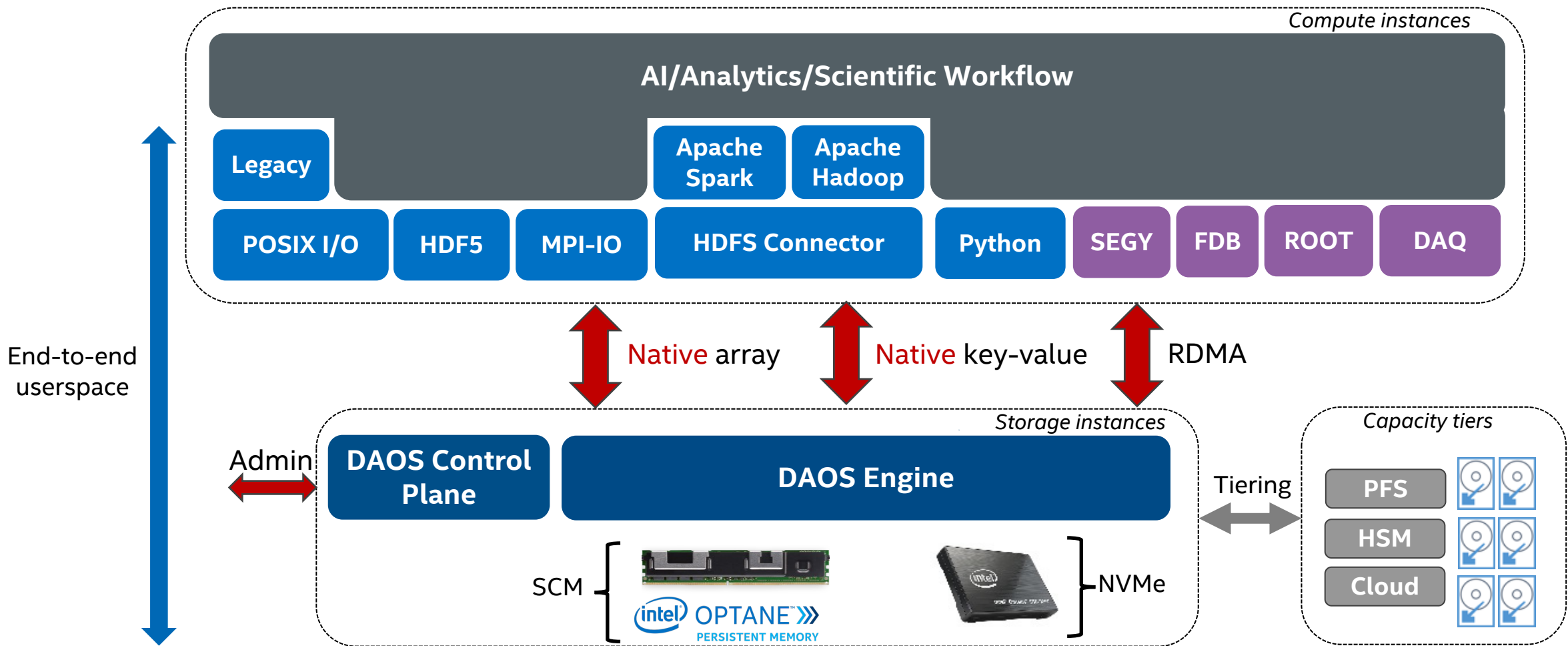
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# DAOS Ecosystem

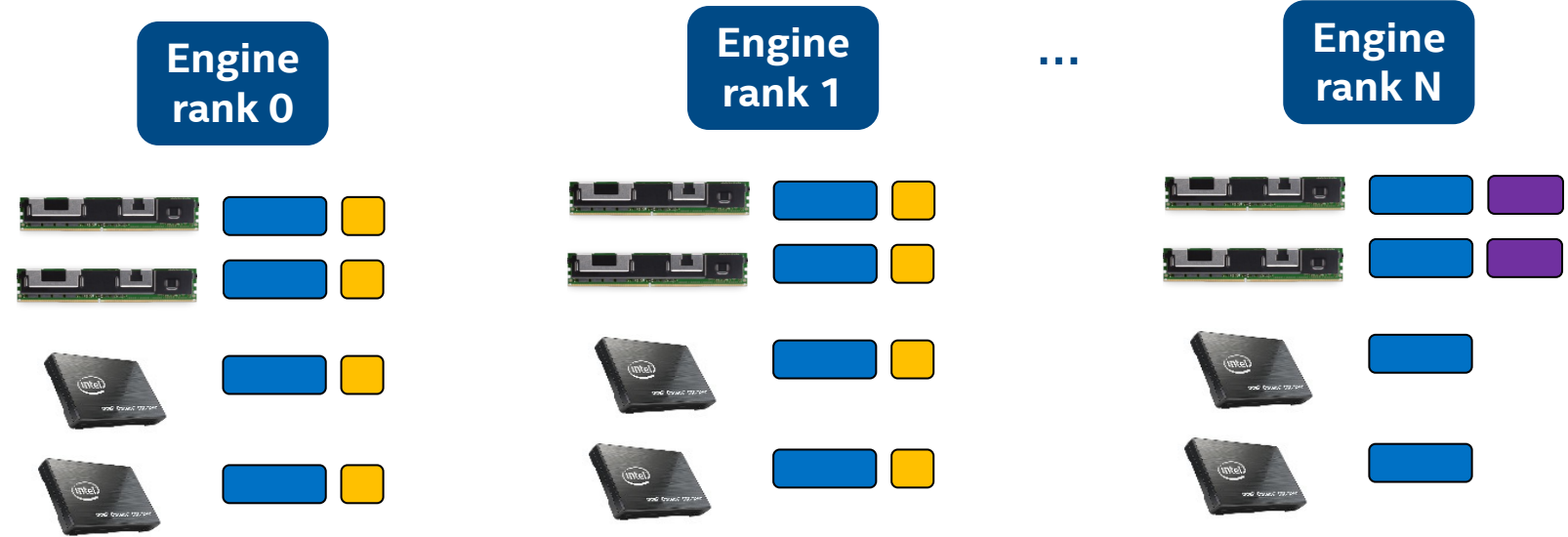
- Generic I/O middleware supported today
- Domain-specific data models under development in co-design with partners



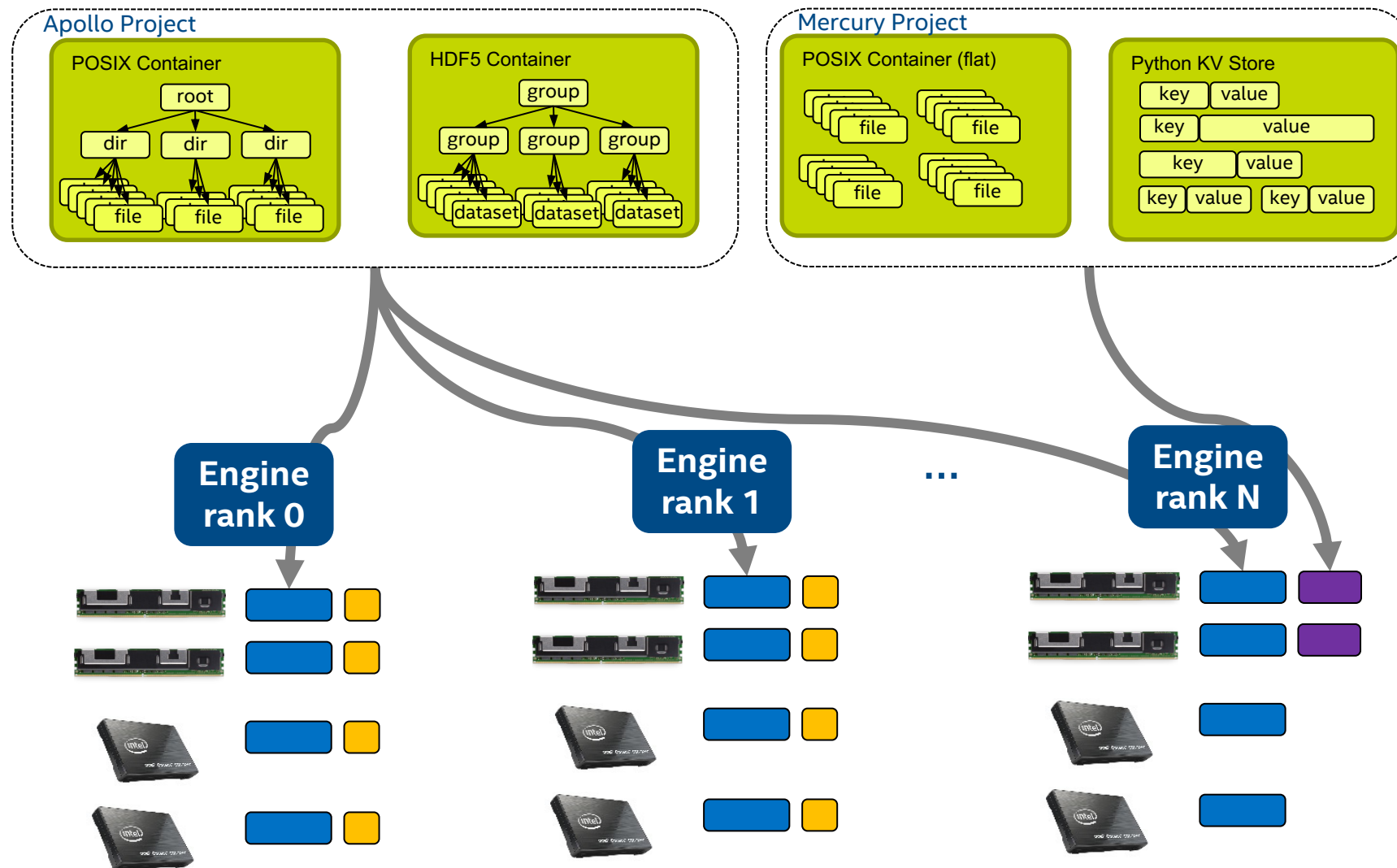
# DAOS Data Model: Pools

Example:

Pool 1		Project Apollo	100PB usable	20TB/s	200M IOPS
Pool 2		Project Gemini	10PB usable	2TB/s	20M IOPS
Pool 3		Project Mercury	30TB usable	80GB/s	2M IOPS



# DAOS Data Model: Container



# Connect to Pool

- First thing you usually do in your program is initialize DAOS and connect to your pool:
  - `int daos_init(void);`
  - `int daos_pool_connect(const char *pool, const char *sys, unsigned int flags, daos_handle_t *poh, daos_pool_info_t *info, daos_event_t *ev);`
- When finished, disconnect from your pool and finalize daos:
  - `int daos_pool_disconnect(daos_handle_t poh, daos_event_t *ev);`
  - `int daos_fini(void);`
- In an MPI program, consider connecting only from 1 client, and sharing the pool handle (poh) using the pool l2g, g2l functions:
  - `daos_pool_local2global`
  - `daos_pool_global2local`

# Creating a Container

- Using the daos tool:

```
daos cont create mypool --label=mycont
```

```
Container UUID : 5d33d6e0-6c8b-4bf5-bb49-c8723bf30c91  
Container Label: mycont  
Container Type : unknown
```

```
Successfully created container 5d33d6e0-6c8b-4bf5-bb49-c8723bf30c91
```

- Using the API:

- `int daos_cont_create_with_label (daos_handle_t poh, const char *label, daos_prop_t *cont_prop, uuid_t *uuid, daos_event_t *ev);`
- `int daos_cont_destroy (daos_handle_t poh, const char *cont, int force, daos_event_t *ev);`

# Accessing a Container

- Need to open a container to access object in it:
  - `int daos_cont_open(daos_handle_t poh, const char *cont, unsigned int flags, daos_handle_t *coh, daos_cont_info_t *info, daos_event_t *ev);`
- Close container when done:
  - `int daos_cont_close(daos_handle_t coh, daos_event_t *ev);`
- In an MPI program, consider opening only from 1 client, and sharing the container handle (coh) using the cont l2g, g2l functions:
  - `daos_cont_local2global`
  - `daos_cont_global2local`



# Recap Program Flow

```
#include <daos.h>

int main(int argc, char **argv)
{
    daos_handle_t    poh, coh;

    daos_init();
    daos_pool_connect("mypool", NULL, DAOS_PC_RW, &poh, NULL, NULL);
    daos_cont_create_with_label(poh, "mycont", NULL, NULL, NULL);
    daos_cont_open(poh, "mycont", DAOS_COO_RW, &coh, NULL, NULL);

    /** do things */

    daos_cont_close(coh, NULL);
    daos_pool_disconnect(poh, NULL);
    daos_fini();
    return 0;
}
```

# DAOS Object Types

## ■ DAOS Object Types:

- DAOS KV
- DAOS ARRAY
- DAOS Multi-Level KV (lower level)

## ■ Object ID 128-bit space:

- Lower 96 bits set by user
  - Unique OID allocator available in API for convenience
- OID Embeds:
  - Object type
  - Object class (redundancy level and type – Replication, EC, None)

```
daos_obj_generate_oid(  
    coh,  
    *oid /* in/out */,  
    type,  
    class_id /* optional */,  
    hints /* optional */,  
    args /* reserved */);
```

# DAOS KV Object

- KV store API that provides:

- Put, Get, Remove, List

- API:

- `int daos_kv_open(daos_handle_t coh, daos_obj_id_t oid, unsigned int mode, daos_handle_t *oh, daos_event_t *ev);`
- `int daos_kv_put(daos_handle_t oh, daos_handle_t th, uint64_t flags, const char *key, daos_size_t size, const void *buf, daos_event_t *ev);`
- `int daos_kv_get(daos_handle_t oh, daos_handle_t th, uint64_t flags, const char *key, daos_size_t *size, void *buf, daos_event_t *ev);`
- `int daos_kv_remove(daos_handle_t oh, daos_handle_t th, uint64_t flags, const char *key, daos_event_t *ev);`
- `int daos_kv_list(daos_handle_t oh, daos_handle_t th, uint32_t *nr, daos_key_desc_t *kds, d_sg_list_t *sgl, daos_anchor_t *anchor, daos_event_t *ev);`
- `int daos_kv_close(daos_handle_t oh, daos_event_t *ev);`
- `int daos_kv_destroy(daos_handle_t oh, daos_handle_t th, daos_event_t *ev);`

# KV put/get example

```
/** init, connect, cont_open */

oid.hi = 0;
oid.lo = 1;
daos_obj_generate_oid(coh, &oid, DAOS_OF_KV_FLAT, 0, 0, 0);
daos_kv_open(coh, oid, DAOS_OO_RW, &kv, NULL);

/** set val buffer and size */
daos_kv_put(kv, DAOS_TX_NONE, 0, "key1", val_len1, val_buf1, NULL);
daos_kv_put(kv, DAOS_TX_NONE, 0, "key2", val_len2, val_buf2, NULL);

/** to fetch, can query the size first if not known */
daos_kv_get(kv, DAOS_TX_NONE, 0, "key1", &size, NULL, NULL);
get_buf = malloc (size);
daos_kv_get(kv, DAOS_TX_NONE, 0, "key1", &size, get_buf, NULL);
daos_kv_close(kv, NULL);

/** free buffer, cont_close, disconnect, finalize */
```

# KV list example

```
/** enumerate keys in the KV */
daos_anchor_t    anchor = {0};
d_sg_list_t      sgl;
d_iov_t          sg_iov;

/** size of buffer to hold as many keys in memory */
buf = malloc(ENUM_DESC_BUF);
d_iov_set(&sg_iov, buf, ENUM_DESC_BUF);
sgl.sg_nr        = 1;
sgl.sg_nr_out     = 0;
sgl.sg_iovs       = &sg_iov;
```

```
daos_key_desc_t kds[ENUM_DESC_NR];

while (!daos_anchor_is_eof(&anchor)) {
    /** how many keys to attempt to fetch in one call */
    uint32_t      nr = ENUM_DESC_NR;

    memset(buf, 0, ENUM_DESC_BUF);
    daos_kv_list(kv, DAOS_TX_NONE, &nr, kds, &sgl,
                  &anchor, NULL);

    if (nr == 0)
        continue;

    /** buf now container nr keys */
    /** kds arrays has length of each key */
}
```

# KV Conditional Operations

- By default, KV put/get operations do not check “existence” of key before operations:
  - Put on a key overwrites the value of that key
  - Get of a key does not fail if key does not exist, just returns 0 size.
  - Remove of a key does not fail if key does not exist.
- One can use conditional flags to achieve a different behavior:
- **DAOS\_COND\_KEY\_INSERT:** Insert a key if it doesn't exist, fail if it does.
- **DAOS\_COND\_KEY\_UPDATE:** Update a key if it exists, fail if it doesn't.
- **DAOS\_COND\_KEY\_GET:** Get key value if it exists, fail if it doesn't.
- **DAOS\_COND\_KEY\_REMOVE:** Remove a key if it exists, fail if it doesn't.

# DAOS Array Object

- Array object to manage records:
  - 1 Dimensional (multi-dimensional arrays to be supported in the future)
- Array Management API:
  - `int daos_array_create(daos_handle_t coh, daos_obj_id_t oid, daos_handle_t th, daos_size_t cell_size, daos_size_t chunk_size, daos_handle_t *oh, daos_event_t *ev);`
  - `int daos_array_open(daos_handle_t coh, daos_obj_id_t oid, daos_handle_t th, unsigned int mode, daos_size_t *cell_size, daos_size_t *chunk_size, daos_handle_t *oh, daos_event_t *ev);`
  - `int daos_array_open_with_attr(daos_handle_t coh, daos_obj_id_t oid, daos_handle_t th, unsigned int mode, daos_size_t cell_size, daos_size_t chunk_size, daos_handle_t *oh, daos_event_t *ev);`
  - `int daos_array_close(daos_handle_t oh, daos_event_t *ev);`
  - `int daos_array_destroy(daos_handle_t oh, daos_handle_t th, daos_event_t *ev);`

# DAOS Array Access API

- Reading & writing record to an Array:
  - `int daos_array_read(daos_handle_t oh, daos_handle_t th, daos_array_iod_t *iod, d_sg_list_t *sgl, daos_event_t *ev);`
  - `int daos_array_write(daos_handle_t oh, daos_handle_t th, daos_array_iod_t *iod, d_sg_list_t *sgl, daos_event_t *ev);`
  - `int daos_array_get_size(daos_handle_t oh, daos_handle_t th, daos_size_t *size, daos_event_t *ev);`
  - `int daos_array_set_size(daos_handle_t oh, daos_handle_t th, daos_size_t size, daos_event_t *ev);`
  - `int daos_array_get_attr(daos_handle_t oh, daos_size_t *chunk_size, daos_size_t *cell_size);`



# DAOS Array example

```
/** create array - if array exists just open it */
daos_array_create(coh, oid, DAOS_TX_NONE, 1, 1048576, &array, NULL);

daos_array_iod_t iod;
d_sg_list_t      sgl;
daos_range_t     rg;
d_iov_t          iov;

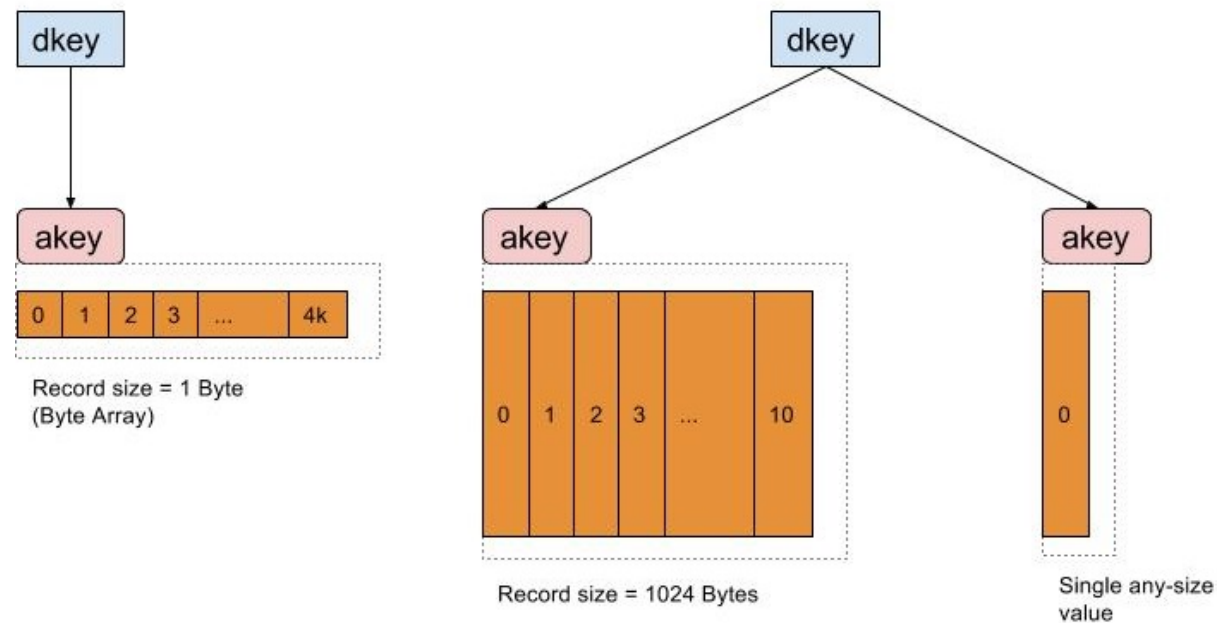
/** set array location */
iod.arr_nr = 1; /** number of ranges / array iovec */
rg.rg_len = BUFLen; /** length */
rg.rg_idx = rank * BUFLen; /** offset */
iod.arr_rgs = &rg;

/** set memory location, each rank writing BUFLen */
sgl.sg_nr = 1;
d_iov_set(&iov, buf, BUFLen);
sgl.sg_iovs = &iov;

daos_array_write(array, DAOS_TX_NONE, &iod, &sgl, NULL);
daos_array_read(array, DAOS_TX_NONE, &iod, &sgl, NULL);
daos_array_close(array, NULL);
```

# DAOS Multi-Level KV Object

- 2 level keys:
  - Distribution Key - Dkey (collocate all entries under it), holds multiple akeys
  - Attribute Key - Akey (lower level to address records)
  - Both are opaque (support any size / type)
- Value types (under akey):
  - Single value: one blob (traditional value in KV store)
  - Array value:
    - 1 record size per akey
    - Array of records that can be updates via different extents / iovec



- Intentionally very flexible, rich API; but at the expense of higher complexity for the regular user.

# Object Management API

- `int daos_obj_open(daos_handle_t coh, daos_obj_id_t oid, unsigned int mode, daos_handle_t *oh, daos_event_t *ev);`
- `int daos_obj_close(daos_handle_t oh, daos_event_t *ev);`
- `int daos_obj_punch(daos_handle_t oh, daos_handle_t th, uint64_t flags, daos_event_t *ev);`
- `int daos_obj_punch_dkeys(daos_handle_t oh, daos_handle_t th, uint64_t flags, unsigned int nr, daos_key_t *dkeys, daos_event_t *ev);`
- `int daos_obj_punch_akeys(daos_handle_t oh, daos_handle_t th, uint64_t flags, daos_key_t *dkey, unsigned int nr, daos_key_t *akeys, daos_event_t *ev);`

# Object IO API

```
▪ int daos_obj_update(daos_handle_t oh, daos_handle_t th,  
    uint64_t flags, daos_key_t *dkey, unsigned int nr,  
    daos_iod_t *iods, d_sg_list_t *sgls, daos_event_t *ev);
```



```
daos_key_t iod_name; /* akey */  
daos_iod_type_t iod_type; /* value type (single value or array value) */  
daos_size_t iod_size; /* value or record size */  
uint32_t iod_nr; /* number of extents (1 for SV) */  
daos_recx_t *iod_recxs; /* array of extents – offset, length pairs */  
  
uint32_t sg_nr;  
uint32_t sg_nr_out;  
d_iov_t *sg_iovs;
```

```
▪ int daos_obj_fetch(daos_handle_t oh, daos_handle_t th,  
    uint64_t flags, daos_key_t *dkey, unsigned int nr,  
    daos_iod_t *iods, d_sg_list_t *sgls, daos_iom_t *ioms,  
    daos_event_t *ev);
```

# Object Enumerate API

```
int daos_obj_list_dkey(daos_handle_t oh, daos_handle_t  
th, uint32_t *nr, daos_key_desc_t *kds, d_sg_list_t  
*sgl, daos_anchor_t *anchor, daos_event_t *ev);
```

```
int daos_obj_list_akey(daos_handle_t oh, daos_handle_t  
th, daos_key_t *dkey, uint32_t *nr, daos_key_desc_t  
*kds, d_sg_list_t *sgl, daos_anchor_t *anchor,  
daos_event_t *ev);
```

# DAOS Object Update Example

```
daos_obj_open(coh, oid, DAOS_OO_RW, &oh, NULL);
d_iov_set(&dkey, "dkey1", strlen("dkey1"));

d_iov_set(&sg_iov, buf, BUFLLEN);
sgl[0].sg_nr = 1;
sgl[0].sg_iovs = &sg_iov;
sgl[1].sg_nr = 1;
sgl[1].sg_iovs = &sg_iov;

d_iov_set(&iod[0].iod_name, "akey1", strlen("akey1"));
d_iov_set(&iod[1].iod_name, "akey2", strlen("akey2"));

iod[0].iod_nr = 1;
iod[0].iod_size = BUFLLEN;
iod[0].iod_recxs = NULL;
iod[0].iod_type = DAOS_IOD_SINGLE;

iod[1].iod_nr = 1;
iod[1].iod_size = 1;
recx.rx_nr = BUFLLEN;
recx.rx_idx = 0;
iod[1].iod_recxs = &recx;
iod[1].iod_type = DAOS_IOD_ARRAY;

daos_obj_update(oh, DAOS_TX_NONE, 0, &dkey, 2, &iod, &sgl, NULL);
```

# DAOS Object Fetch Example

```
daos_obj_open(coh, oid, DAOS_OO_RW, &oh, NULL);
d_iov_set(&dkey, "dkey1", strlen("dkey1"));

d_iov_set(&sg_iov, buf, BUFLen);
sgl[0].sg_nr = 1;
sgl[0].sg_iovs = &sg_iov;
sgl[1].sg_nr = 1;
sgl[1].sg_iovs = &sg_iov;

d_iov_set(&iod[0].iod_name, "akey1", strlen("akey1"));
d_iov_set(&iod[1].iod_name, "akey2", strlen("akey2"));

iod[0].iod_nr = 1;
iod[0].iod_size = BUFLen; /** if size is not known, use DAOS_REC_ANY and NULL sgl */
iod[0].iod_recxs = NULL;
iod[0].iod_type = DAOS_IOD_SINGLE;

iod[1].iod_nr = 1;
iod[1].iod_size = 1; /** if size is not known, use DAOS_REC_ANY and NULL sgl */
recx.rx_nr = BUFLen;
recx.rx_idx = 0;
iod[1].iod_recxs = &recx;
iod[1].iod_type = DAOS_IOD_ARRAY;

daos_obj_fetch(oh, DAOS_TX_NONE, 0, &dkey, 2, &iod, &sgl, NULL, NULL);
```

# More examples

- [https://github.com/daos-stack/daos/blob/master/src/tests/simple\\_obj.c](https://github.com/daos-stack/daos/blob/master/src/tests/simple_obj.c)



# Transactions

- Open/close transaction
  - Open returns transaction handle to use in object operations
  - Close just frees the handle (does not commit)
- Commit/abort/restart transaction
- Conflict detection:
  - WR, RW, WW conflicts

```
    daos_tx_open(coh, &th, ...);  
restart:  
    daos_obj_fetch(..., th, ...);  
    daos_obj_update(..., th, ...);  
    daos_obj_fetch(..., th, ...);  
    daos_obj_update(..., th, ...);  
    daos_obj_dkey_punch(..., th, ...);  
    rc = daos_tx_commit(th, ...);  
    if (rc == -DER_RESTART) {  
        daos_tx_restart(th, ...);  
        goto restart;  
    }  
    daos_tx_close(th, ...);
```

