RFC: Improvements for SWMR File Access and Dataset Append

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This RFC describes the changes to the HDF5 library that improve the SWMR (Single-writer/multiple-read) file access model and provide better support for dataset append operation.

# Introduction

The modifications described in this RFC cover improvements to two areas in the HDF5 library:

* The process in enabling SWMR writing for an open HDF5 file
  + A new public routine *H5Fstart\_swrm\_write()* to simplify the steps in setting up and enabling a file for SWMR writing
* The flush behavior when appending to a dataset and when flushing an HDF5 object
  + Two new public routines *H5Pget/set\_append\_flush()* to control when a dataset flush will occur during an append operation and to invoke an application callback function
  + Two new public routines *H5Pget/set\_object\_flush\_cb()* to invoke an application callback function when an object flush occurs

# Enhancement to SWMR file access

The SWMR file access model follows the standard HDF5 model: the writer and readers will need to indicate SWMR access using file access flags with the *H5Fcreate* and *H5Fopen* calls. To switch to SWMR-safe operations after creating/opening a file, a writer application has to close and reopen the file with SWMR access flags. To improve usability for the writer applications, the library will provide a new public routine, H5Fstart\_swmr\_write, to activate SWMR writing mode for an opened file.

The HDF5 library will use the file consistency flags in the file’s superblock data structure (*status\_flags* fieldin *struct* *H5F\_super\_t*) to mark a file as safe for SWMR writing. The marking will be removed upon file closing. Once the file is marked as SWMR-safe, a user cannot switch back to the previous mode. Also, a user cannot activate SWMR writing mode more than once for an opened file.

## H5Fstart\_swmr\_write

**Name:**

H5Fstart\_swmr\_write

**Signature:**

herr\_tH5Fstart\_swmr\_write*(hid\_t* file\_id*)*

**Purpose:**

Enables SWMR writing mode for a file.

**Description:**

H5Fstart\_swmr\_write will activate SWMR writing mode for a file associated with file\_id. This routine will prepare and ensure the file is safe for SWMR writing as follows:

* Check that the file is open with write access (H5F\_ACC\_RDWR).
* Check that the file is open with the latest library format to ensure data structures with check-summed metadata are used.
* Check that the file is not already marked in SWMR writing mode.
* Enable reading retries for check-summed metadata to remedy possible checksum failures from reading inconsistent metadata on a system that is not atomic.
* Turn off usage of the library’s accumulator to avoid possible ordering problem on a system that is not atomic.
* Perform a flush of the file’s data buffers and metadata to set a consistent state for starting SWMR write operations.

Library objects are groups, datasets, and named data types. For the current implementation, groups and datasets can remain open when activating SWMR writing mode, but not named datatypes. Attributes attached to objects cannot remain open either.

**Parameters:**

|  |  |
| --- | --- |
| *hid\_t* file\_id | IN: A file identifier. |
|  |  |

**Returns:**

Returns a non-negative value if successful; otherwise returns a negative value.

**Example Usage:**

The example below illustrates the usage of this routine to activate SWMR writing mode for an opened file.

/\*

\* The writer process

\*/

/\* Create a copy of the file access property list \*/

fapl\_id = H5Pcreate(H5P\_FILE\_ACCESS);

/\* Set to use the latest library format \*/

H5Pset\_libver\_bounds(fapl\_id, H5F\_LIBVER\_LATEST, H5F\_LIBVER\_LATEST);

/\* Create a file with the latest library format \*/

file\_id = H5Fcreate(filename, H5F\_ACC\_TRUNC, H5P\_DEFAULT, fapl\_id);

:

:

:

/\* Perform operations that are not SWMR-safe. \*/

:

:

:

/\* Start a concurrent SWMR reader process (see coding below) at this point

will fail because the file is not marked as SWMR-safe \*/

/\* Enable SWMR writing mode \*/

H5Fstart\_swmr\_write(file\_id);

/\* Start a concurrent SWMR reader process (see coding below) at this point

will succeed because the file is marked as SWMR-safe \*/

/\* Perform SWMR-safe operations \*/

:

:

:

/\* Close the file \*/

H5Fclose(file\_id);

/\* Close the property list \*/

H5Pclose(fapl\_id);

/\*

\* The SWMR reader process

\*/

read\_file\_id = H5Fopen(filename, H5F\_ACC\_RDONLY|H5F\_ACC\_SWMR\_READ, fapl\_id);

/\* Perform reading operations \*/

:

:

:

/\* Close the file \*/

H5Fclose(read\_file\_id);

# Support for dataset append operation and object flush

The dataset append operation for SWMR write usually consists of extending the dataset’s dataspace in a particular dimension and writes data elements to the newly extended region in the dataset. The high-level public routine *H5DOappend* condenses such dataspace and dataset write operations into a single function, thus eliminating much application code.

To provide flexibility for a user to manage the flush behavior of dataset elements during the append operation via *H5DOappend*, the following routines are provided to trigger actions on appends and flushes:

1. *H5Pget/set\_append\_flush()* for a dataset access property list
2. *H5Pget/set\_object\_flush\_cb()* for a file access property list

Note that these routines will apply for both SWMR and non-SWMR access.

## H5DOappend

**Name:**

H5DOappend

**Signature:**

*herr\_t* H5DOappend(*hid\_t* dset\_id, *hid\_t* dxpl\_id, *unsigned* index, *size\_t* num\_elem, *hid\_t* memtype, *const void* \*buffer)

**Purpose:**

Appends data to a dataset along a specified dimension.

**Description:**

The H5DOappend routine extends a dataset by num\_elem number of elements along a dimension specified by a dimension index and writes buffer of elements to the dataset. Dimension index is 0-based. Elements’ type is described by memtype.

This routine combines calling H5Dset\_extent, H5Sselect\_hyperslab and H5Dwrite into a single, routine that simplifies application development for the common case of appending elements to an existing dataset.

For multi-dimensional dataset, appending to one dimension will write a contiguous hyperslab over the other dimensions.  For example, if a 3-D dataset has dimension sizes (3, 5, 8), extending the 0th dimension (currently of size 3) by 3 will append 3\*5\*8 = 120 elements (which must be pointed to by the buffer parameter) to the dataset, making its final dimension sizes (6, 5, 8).

If a dataset has more than one unlimited dimension, any of those dimensions may be appended to, although only along one dimension per call to H5DOappend.

**Parameters:**

|  |  |
| --- | --- |
| *hid\_t* dset\_id  *hid\_t* dxpl\_id  *unsigned* index  *size\_t* num\_elem  *hid\_t* memtype  *void \**buffer | IN: Dataset identifier.  IN: Dataset transfer property list identifier.  IN: Dimension number (0-based)  IN: Number of elements to add along the dimension  IN: Memory type identifier  IN: Data buffer |
|  |  |

**Returns:**

Returns a non-negative value if successful; otherwise returns a negative value.

**Example Usage:**

The example below for H5Pset\_append\_flush illustrates the usage of this public routine to append to a dataset.

## H5Pset\_append\_flush

**Name:**

H5Pset\_append\_flush

**Signature:**

herr\_tH5Pset\_append\_flush *(hid\_t* dapl\_id*,* int ndims, const hsize\_t boundary[], *H5D\_append\_cb\_t* func, *void \**user\_data*)*

**Purpose:**

Sets two actions to perform when the size of a dataset’s dimension being appended reaches a specified boundary.

**Description:**

H5Pset\_append\_flush sets the following two actions to perform for a dataset associated with the dataset access property list dapl\_id:

1. Call the callback function func set in the property list
2. Flush the dataset associated with the dataset access property list

While a user is appending data to a dataset via *H5DOappend* and the dataset’s newly extended dimension size hits a specified boundary, the library will first perform action #1 listed above. Upon return from the callback function, the library will then perform the above action #2 and return to the user. If no boundary is hit or set, the two actions above are not invoked.

The specified boundary is indicated by the parameter boundary. It is a 1-dimensional array with ndims elements, which should be the same as the rank of the dataset’s dataspace. While appending to a dataset along a particular dimension indexvia *H5DOappend*, the library determines a boundary is reached when the resulted dimension size is divisible by boundary[index]. A zero value for boundary[index] indicates no boundary is set for that dimension index.

The setting of this property will apply only for a chunked dataset with extendible dataspace. A dataspace is extendible when it is defined with either one of the following:

* Dataspace with fixed current and maximum dimension sizes
* Dataspace with at least one unlimited dimension for its maximum dimension sizes

When creating or opening a chunked dataset, the library will check whether the boundary as specified in the access property list is set up properly. The library will fail the dataset create or open when detecting the following conditions:

* The number of elements for boundary, ndims, is not the same as the dataset rank.
* A non-zero boundary value is specified for a non-extendible dimension.

The callback function func must conform to the prototype defined as below:

typedef *herr\_t* (H5D\_append\_cb\_t)(*hid\_t* dataset\_id, *hsize\_t* \*cur\_dims, *void \**user\_data)

where

dataset\_id is the dataset identifier

cur\_dims is the dataset’s current dimension sizes when a boundary is hit

user\_data is the user-defined input data.

**Parameters:**

|  |  |
| --- | --- |
| *hid\_t* dapl\_id  int ndims  hsize\_t \*boundary  *H5D\_append\_cb\_t* func  *void \**user\_data | IN: Dataset access property list identifier.  IN: The number of elements for boundary.  IN: The dimension sizes used to determine the boundary.  IN: The user-defined callback function.  IN: The user-defined input data. |
|  |  |

**Returns:**

Returns a non-negative value if successful; otherwise returns a negative value.

**Example Usage:**

The example below illustrates the usage of this public routine to manage the flush behavior while appending to a dataset.

hsize\_t dims[2] = {0, 100};

hsize\_t max\_dims[2] = {H5S\_UNLIMITED, 100};

hsize\_t boundary\_dims[2] = {5, 0};

unsigned counter;

void \*buf;

hid\_t file\_id;

hid\_t dataset\_id, dapl\_id, type;

/\* Open the file \*/

file\_id = H5Fopen(FILE, H5F\_ACC\_RDWR|H5F\_ACC\_SWMR\_WRITE, H5P\_DEFAULT);

/\* Create a copy of the dataset access property list \*/

dapl\_id = H5Pcreate(H5P\_DATASET\_ACCESS);

/\* Set up the append property values \*/

/\* *boundary\_dims[0]=5*: to invoke callback and flush every 5 lines \*/

/\* *boundary\_dims[1]=0*: no boundary is set for the non-extendible dimension \*/

/\* *append\_cb*: callback function to invoke when hitting boundary (see below) \*/

/\* *counter*: user data to pass along to the callback function \*/

H5Pset\_append\_flush(dapl\_id, 2, boundary\_dims, append\_cb, &counter);

/\* DATASET is a 2-dimensional chunked dataset with dataspace:

*dims[]* and *max\_dims[]* \*/

dataset\_id = H5Dopen2(file\_id, “dataset”, dapl\_id);

/\* Get the dataset’s datatype \*/

type = H5Dget\_type(dataset\_id);

/\* Append 50 lines along the unlimited dimension to the dataset \*/

for(n = 0; n < 50; n++) {

/\* Append 1 line to the dataset \*/

/\* Whenever hitting the specified boundary i.e., every 5 lines,

the library will invoke *append\_cb()* and then flush the dataset. \*/

H5DOappend(dataset\_id, H5P\_DEFAULT, 0, 1, type, buf);

}

:

:

:

/\* counter will be equal to 10 \*/

:

:

:

/\* The callback function \*/

static herr\_t

append\_cb(hid\_t dset\_id, hsize\_t \*cur\_dims, void \*\_udata)

{

unsigned \*count = (unsigned \*)\_udata;

++(\*count++);

return 0;

} /\* append\_cb() \*/

## H5Pget\_append\_flush

**Name:**

H5Pget\_append\_flush

**Signature:**

herr\_tH5Pget\_append\_flush *(hid\_t* dapl\_id*, int* ndims, *hsize*\_t boundary[], *H5D\_append\_cb\_t \**func, *void \*\**user\_data*)*

**Purpose:**

Retrieves the values of the append property that is set up in the dataset access property list.

**Description:**

H5Pget\_append\_flush obtains the following information from the dataset access property list dapl\_id:

* boundary[]—the sizes set up in the access property list that is used to determine when a dataset dimension size hits the boundary. Only at most ndims boundary sizes are retrieved, and ndims will not exceed the corresponding value that is set in the property list.
* func—the user-defined callback function to invoke when a dataset’s appended dimension size reaches a boundary.
* user\_data—the user-defined input data for the callback function.

**Parameters:**

|  |  |
| --- | --- |
| *hid\_t* dapl\_id  *int* ndims  *hsize\_t* \*boundary[]  *H5D\_append\_cb\_t \**func  *void \*\**user\_data | IN: Dataset access property list identifier.  IN: The number of elements for boundary.  IN: The dimension sizes used to determine the boundary .  IN: The user-defined callback function.  IN: The user-defined input data. |
|  |  |

**Returns:**

Returns a non-negative value if successful; otherwise returns a negative value.

**Example Usage:**

The example below illustrates the usage of this public routine to obtain the append property values that is set up in the dataset access property list.

hid\_t file\_id;

hid\_t dapl\_id, dataset\_id, dapl;

hsize\_t dims[2] = {0, 100};

hsize\_t max\_dims[2] = {H5S\_UNLIMITED, 100};

hsize\_t boundary\_dims[2] = {5, 0};

int counter;

hsize\_t ret\_boundary[1];

H5D\_append\_flush\_cb\_t ret\_cb;

void \*ret\_udata;

/\* Open the file \*/

file\_id = H5Fopen(FILE, H5F\_ACC\_RDWR|H5F\_ACC\_SWMR\_WRITE, H5P\_DEFAULT);

/\* Create a copy of the dataset access property list \*/

dapl\_id = H5Pcreate(H5P\_DATASET\_ACCESS);

/\* Set up the append property values \*/

/\* *boundary\_dims[0]=5*: to invoke callback and flush every 5 lines \*/

/\* *boundary\_dims[1]=0*: no boundary is set for the non-extendible dimension \*/

/\* *append\_cb*: callback function to invoke when hitting boundary (see below) \*/

/\* *counter*: user data to pass along to the callback function \*/

H5Pset\_append\_flush(dapl\_id, 2, boundary\_dims, append\_cb, &counter);

/\* DATASET is a 2-dimensional chunked dataset with dataspace:

*dims[]* and *max\_dims[]* \*/

dataset\_id = H5Dopen2(file\_id, “dataset”, dapl\_id);

/\* Get the dataset access property list for DATASET \*/

dapl = H5Dget\_access\_plist(dataset\_id);

/\* Retrieve the append property values for the dataset \*/

/\* Only 1 boundary size is retrieved: *ret\_boundary[0]* is 5 \*/

/\* *ret\_cb* will point to *append\_cb()* \*/

/\* *ret\_udata* will point to *counter* \*/

H5Pget\_append\_flush(dapl, 1, ret\_boundary, &ret\_cb, &ret\_udata);

:

:

:

/\* The callback function \*/

static herr\_t

append\_cb(hid\_t dset\_id, hsize\_t \*cur\_dims, void \*\_udata)

{

unsigned \*count = (unsigned \*)\_udata;

++(\*count++);

return 0;

} /\* append\_cb() \*/

## H5Pset\_object\_flush\_cb

**Name:**

H5Pset\_object\_flush\_cb

**Signature:**

herr\_tH5Pset\_object\_flush\_cb *(hid\_t* fapl\_id*, H5F\_flush\_cb\_t* func, void \*user\_data*)*

**Purpose:**

Sets a callback function to invoke when an object flush occurs in the file.

**Description:**

H5Pset\_object\_flush\_cb sets the callback function to invoke in the file access property list *fapl\_id* whenever an object flush occurs in the file. Library objects are *group*, *dataset*, and *named datatype*. When a user flushes an object via *H5Gflush/H5Dflush/H5Tflush/H5Oflush*, the library will flush the object, invoke the specified callback function, and then return to the user.

The callback function func must conform to the prototype defined as below:

typedef *herr\_t* (\*H5F\_flush\_cb\_t)(*hid\_t* object\_id, *void \**user\_data)

where

object\_id is the identifier of the object which has just been flushed

user\_data is the user-defined input data for the callback function

**Parameters:**

|  |  |
| --- | --- |
| *hid\_t* fapl\_id  *H5F\_flush\_cb\_t* func  *void \**user\_data | IN: Identifier for a file access property list.  IN: The user-defined callback function.  IN: The user-defined input data for the callback function. |
|  |  |

**Returns:**

Returns a non-negative value if successful; otherwise returns a negative value.

**Example Usage:**

The example below illustrates the usage of this routine to set the callback function to invoke when an object flush occurs.

hid\_t file\_id, fapl\_id;

hid\_t dataset\_id, dapl\_id;

unsigned counter;

/\* Create a copy of the file access property list \*

fapl\_id = H5Pcreate(H5P\_FILE\_ACCESS);

/\* Set up the object flush property values \*/

/\* *flush\_cb*: callback function to invoke when an object flushes (see below) \*/

/\* *counter*: user data to pass along to the callback function \*/

H5Pset\_object\_flush\_cb(fapl\_id, flush\_cb, &counter);

/\* Open the file \*/

file\_id = H5Fopen(FILE, H5F\_ACC\_RDWR, H5P\_DEFAULT);

/\* Create a group \*/

gid = H5Gcreate2(fid, “group”, H5P\_DEFAULT, H5P\_DEFAULT\_H5P\_DEFAULT);

/\* Open a dataset \*/

dataset\_id = H5Dopen2(file\_id, DATASET, H5P\_DEFAULT);

/\* The flush will invoke *flush\_cb()* with *counter* \*/

H5Dflush(dataset\_id);

/\* counter will be equal to 1 \*/

:

:

:

/\* The flush will invoke *flush\_cb()* with *counter* \*/

H5Gflush(gid);

/\* counter will be equal to 2 \*/

:

:

:

/\* The callback function for object flush property \*/

static herr\_t

flush\_cb(hid\_t obj\_id, void \*\_udata)

{

unsigned \*flush\_ct = (unsigned\*)\_udata;

++(\*flush\_ct);

return 0;

}

## H5Pget\_object\_flush\_cb

**Name:**

H5Pset\_object\_flush\_cb

**Signature:**

herr\_tH5Pset\_object\_flush\_cb *(hid\_t* fapl\_id*, H5F\_flush\_cb\_t \**func, void

\*\*user\_data*)*

**Purpose:**

Retrieves the object flush property values from the file access property list.

**Description:**

H5Pget\_object\_flush\_cb gets the user-defined callback function that is set in the file access property list *fapl\_id* and stores in the parameter *func*. It also obtains the user-defined input data that is passed along to the callback function in the parameter *user\_data*.

**Parameters:**

|  |  |
| --- | --- |
| *hid\_t* fapl\_id  *H5F\_flush\_cb\_t \**func  *void \*\**user\_data | IN: Identifier for a file access property list.  IN: The user-defined callback function.  IN: The user-defined input data for the callback function. |
|  |  |

**Returns:**

Returns a non-negative value if successful; otherwise returns a negative value.

**Example Usage:**

The example below illustrates the usage of this routine to obtain the object flush property values.

hid\_t fapl\_id;

unsigned counter;

H5F\_object\_flush\_t \*ret\_cb;

unsigned \*ret\_counter;

/\* Create a copy of the file access property list \*/

fapl\_id = H5Pcreate(H5P\_FILE\_ACCESS);

/\* Set up the object flush property values \*/

/\* *flush\_cb*: callback function to invoke when an object flushes (see below) \*/

/\* *counter*: user data to pass along to the callback function \*/

H5Pset\_object\_flush\_cb(fapl\_id, flush\_cb, &counter);

/\* Open the file \*/

file\_id = H5Fopen(FILE, H5F\_ACC\_RDWR, H5P\_DEFAULT);

/\* Get the file access property list for the file \*/

fapl = H5Fget\_access\_plist(file\_id);

/\* Retrieve the object flush property values for the file \*/

H5Pget\_object\_flush\_cb(fapl, &ret\_cb, &ret\_counter);

/\* *ret\_cb* will point to *flush\_cb()* \*/

/\* *ret\_counter* will point to *counter* \*/

:

:

:

/\* The callback function for the object flush property \*/

static herr\_t

flush\_cb(hid\_t obj\_id, void \*\_udata)

{

unsigned \*flush\_ct = (unsigned\*)\_udata;

++(\*flush\_ct);

return 0;

}

# Acknowledgements

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# Revision History

|  |  |
| --- | --- |
| *November 18, 2013:* | Version 1 circulated for comment within The HDF Group SWMR team. |
| Jan 2, 2014 | Version 2 updated based on implementation. |
| Jan 7, 2014 | Version 3 posted on the SWMR FTP site |
| Jan 29, 2014 | Version 4 added RM entry for H5DOaappend function; posted on SWMR FTP site |
| Feb 26, 2014 | Version 5 updated to reflect implementation. |

# References

1. The HDF Group. “RFC: SWMR Requirements and Use Cases,” RFC-THG-2013-02-06.v8,

<ftp://ftp.hdfgroup.uiuc.edu/pub/outgoing/SWMR/doc/SWMR%20Use%20Cases-2013-03-13.pdf> March 13, 2013.