PVFS2 MPI Based Requests
Design Notes

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1 PVFS Requests

PVFS user programs can construct a data structure that represents a specifc set of non-contiguous data that is to be read from or written to a PVFS file. The PVFS library includes a set of routines for creating these structures in a controlled manner. These routines produce an opaque type the PVFS_Request which is actually a pointer to an internal structure, the PINT_Request.

```
typedef struct PINT_Request *PVFS_Request; /* user type for requests */

int PVFS_Request_contiguous(int count, PVFS_Request oldreq,
            PVFS_Request *newreq);

int PVFS_Request_vector(int count, int blocklength, int stride,
            PVFS_Request oldreq, PVFS_Request *newreq);

int PVFS_Request_hvector(int count, int blocklength, int64_t stride,
            PVFS_Request oldreq, PVFS_Request *newreq);

int PVFS_Request_indexed(int count, int *blocklengths,
            int *displacements, PVFS_Request oldreq, PVFS_Request *newreq);

int PVFS_Request_hindexed(int count, int *blocklengths, int64_t *displacements
            PVFS_Request oldreq, PVFS_Request *newreq);

int PVFS_Request_struct(int count, int *blocklengths, int64_t *displacements,
            PVFS_Request *oldreqs, PVFS_Request *newreq);
```

```
int PVFS_Address(void* location, int64_t *address);

int PVFS_Request_extent(PVFS_Request request, int64_t *extent);

int PVFS_Request_size(PVFS_Request request, int *size);

int PVFS_Request_lb(PVFS_Request request, int64_t* displacement);

int PVFS_Request_ub(PVFS_Request request, int64_t* displacement);
```

These routines are based directly on the MPI datatype constructor routines of similar name and have the same semantics.

2 Request Data Structures

The PINT_Request is designed to represent any data layout that can be specified using MPI's MPI_Datatype constructors. The PINT_Request_state is a structure that indicates how much of a request has actually been processed. Using these structures it is possible to process part of a PVFS request, stop, and then resume processing at a later time when resources become available. This document outlines these structures and the algorithms for using them.

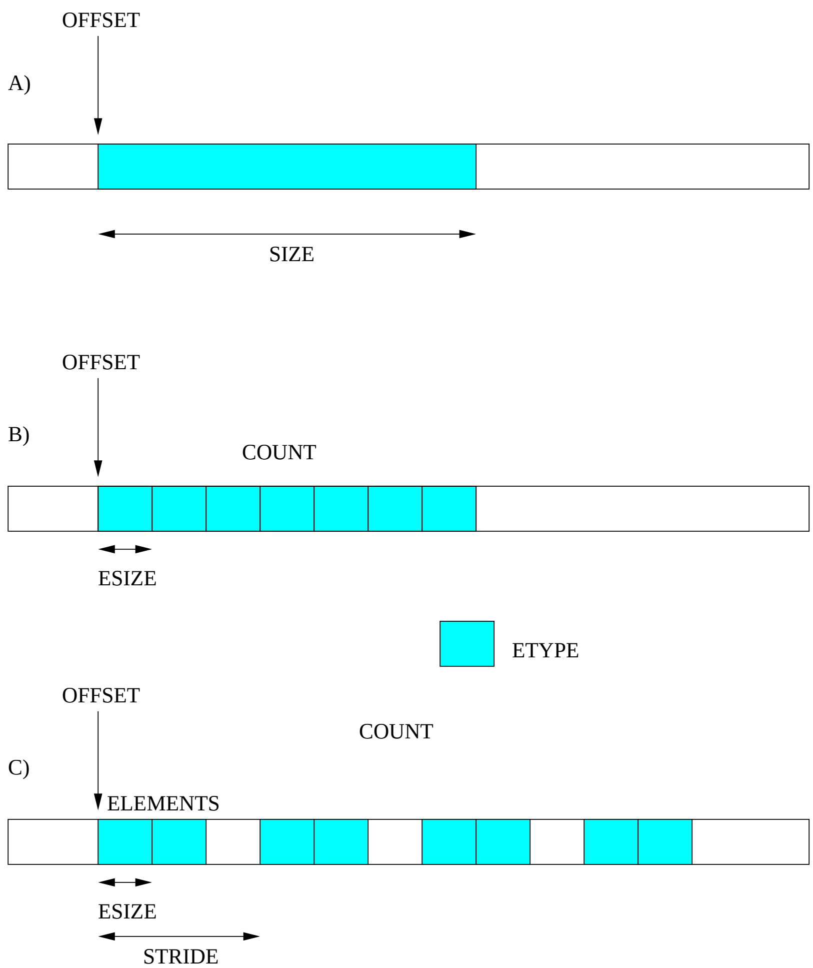
The PINT_Request

```
typedef struct PINT_Request {
   PVFS_offset  offset;     /* offset from start of last set of elements */
   int32_t num_ereqs;  /* number of ereqs in a block */
   PVFS_size    stride;     /* stride between blocks in bytes */
   int32_t num_blocks; /* number of blocks */
   PVFS_offset  ub;         /* upper bound of the type in bytes */
   PVFS_offset  lb;         /* lower bound of the type in bytes */
   PVFS_size    aggregate_size; /* amount of aggregate data in bytes */
   int32_t depth;      /* number of levels of nesting */
   int32_t num_contig_chunks; /* number of contiguous data chunks */
   struct PINT_Request *ereq; /* element type */
   struct PINT_Request *sreq; /* sequence type */
} PINT_Request;
```

A single PINT_Request structure represents num_blocks blocks of num_ereqs elements separated by stride bytes, beginning offest bytes from the logical start of the file, and followed by an arbitrary data layout described by the sequence type. The elements are of an arbitrary data layout described by the element type. The ub, lb, aggregate_size, depth, and num_contig_chunks fields are statistics of the entire data area beginning with the current PINT_Request struct and including the element and sequence types. Depth records the maximum depth of the element type chain. Calls to MPI_Type_contiguous, MPI_Type_vector, and MPI_Type_hvector can be constructed with a single PINT_Request struct and the PINT_Request struct passed in as the element type. Calls to MPI_Type_indexed, MPI_Type_hindexed, and MPI_Type_struct generally utilize the sequence type chain.

Example Requests

The following are a few examples of how request patterns would be represented using the PVFS_Request structure.



Single Contiguous Region Requests

A single contiguous region is represented by a single structure. The region can be specified as SIZE bytes at location OFFSET as in figure A:

```
PTYPE:
   offset = OFFSET
   num_ereqs = SIZE
   stride = 1
   num_blocks = 1
   ub = SIZE
   lb = 0
   aggregate_size = SIZE
   depth = 1
   num_contig_chunks = 1
   etype = PVFS_Request_byte
   stype = NULL
```

Or can be specified as an array of COUNT integers as in figure B:

```
PTYPE:
   offset = OFFSET
   num_ereqs = COUNT
   stride = 1
   num_blocks = 1
   ub = COUNT * 4
   lb = 0
   aggregate_size = COUNT * 4
   depth = 1
   num_contig_chunks = 1
   etype = PVFS_Request_int
   stype = NULL

PVFS_Request_int:
   offset = 0
   num_ereqs = 4
   stride = 1
   num_blocks = 1
   ub = 4
   lb = 0
   aggregate_size = 4
```

```
    depth = 0
    num_contig_chunks = 1
    etype = NULL
    stype = NULL
```

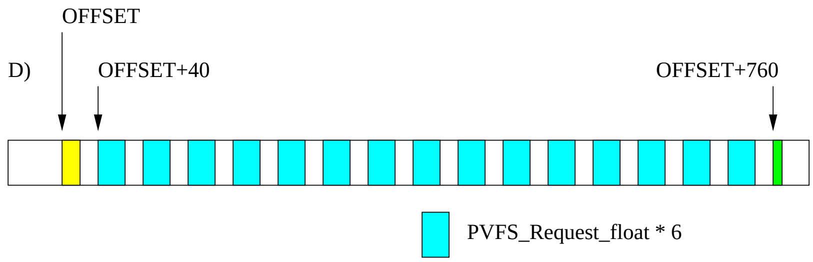
Note that default PVFS_Request exist for standard data types including: PVFS_Request_byte, PVFS_Request_char, PVFS_Request_short, PVFS_Request_int, PVFS_Request_long, PVFS_Request_float, PVFS_Request_double. Each of these standard types is defined with an etype of NULL which indicates that the region is contiguous regardless of the other parameters.

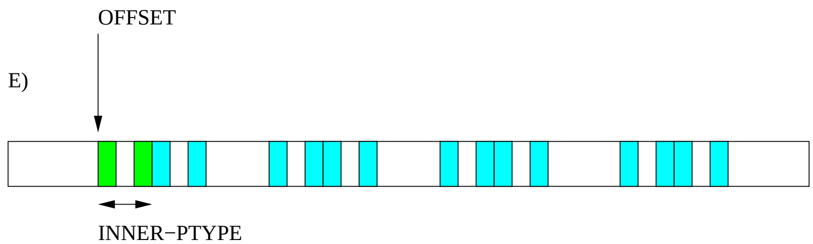
Strided Region Requests

A data area made up of regular strided groups of contiguous elements can also be represented with a single PINT_Request structure. A region consisting of GROUPS groups of ELEMENTS items of type ETYPE with a size of ESIZE each with a stride between the first element of each group of STRIDE bytes would be as in figure C:

```
PTYPE:
    offset = OFFSET
    num_ereqs = ELEMENTS
    stride = STRIDE
    num_blocks = GROUPS
    ub = ((GROUPS - 1) * STRIDE) + (ELEMENTS * ESIZE)
    lb = 0
    aggregate_size = GROUPS * ELEMENTS * ESIZE
    depth = 1
    num_contig_chunks = GROUPS
    etype = ETYPE
    stype = NULL
```

Once again this assumes that ETYPE is a contiguous type.





Sequential Requests

A data area may consist of a region that conforms to one type, followed by a region that conforms to another. Example might include a strided region where one wants to begin and/or end in the middle of a group, rather than have a integral number of whole groups, or may be two unrelated segments of data. For this, a sequence of PINT_Request structures is specified using the stype field to determine the sequence. The offset is specified relative to the beginning of the data area.

In this example we have a strided region shown in D. We want to start 8 bytes into the first group (yellow), then have 15 whole groups (blue), and finally end 4 bytes into the last group (green). Each group is 6 elements, and each element is a float (4 bytes). The stride between groups is 48 bytes (12 floats).

```
FIRST-PTYPE:
   offset = OFFSET
   num_ereqs = 4
   stride = 1
   num_blocks = 1
   ub = 764
   lb = 0
   aggregate_size = 380
   depth = 1
   num_contig_chunks = 17
   etype = PVFS_Request_float
   stype = NEXT-PTYPE
```

```
NEXT-PTYPE:
   offset = OFFSET + 40
   num_ereqs = 6
   stride = 48
   num_blocks = 15
   ub = 764
   lb = 40
   aggregate_size = 364
   depth = 1
   num_contig_chunks = 16
   etype = PVFS_Request_float
   stype = LAST-PTYPE

LAST-PTYPE:
   offset = OFFSET + 760
   num_ereqs = 1
   stride = 1
   num_blocks = 1
   ub = 764
   lb = 760
   aggregate_size = 4
   depth = 1
   num_contig_chunks = 1
   etype = PVFS_Request_float
   stype = NULL
```

Note that ub, lb, aggregate_size, depth, and num_contig_chunks always refers to the region represented down stream of the current PINT_Request record, and not the whole region, however ub and lb are still expressed in terms of the entire data area.

Nested Types

Any request can be built on top of another request. When the base request is contiguous the result is as above, but when the base request is not contiguous things are more complicated. Examples include nested strided regions and vectors of records that are only partially accessed.

The following is a nested strided region. There are 4 groups of two "elements," with a stride of 8 elements. Each element consts of 2 groups of 6 integers (one element shown in green), with a stride of 48 bytes.

```
OUTER-PTYPE:
   offset = OFFSET
```

```
        num_ereqs = 2
        stride = 768
        num_blocks = 4
        ub = 3264
        lb = 0
        aggregate_size = 384
        depth = 2
        num_contig_chunks = 16
        etype = INNER-PTYPE
        stype = NULL

    INNER-PTYPE:
        offset = 0
        num_ereqs = 6
        stride = 48
        num_blocks = 2
        ub = 96
        lb = 0
        aggregate_size = 48
        depth = 1
        num_contig_chunks = 2
        etype = PVFS_Request_int
        stype = NULL
```

Note that the offset, ub, and lb are in terms of the inner elements and not of the entire buffer, thus the offset is the offset from the beginning of that element to the first bit of data in that element.

3 The PINT_Request_state

When processing a request described with a PVFS_Request the following structures are used to keep track of how much of the request has been processed.

```
typedef struct PINT_reqstack {
    int32_t el;       /* number of element being processed */
    int32_t maxel;    /* total number of these elements to process */
    PINT_Request *rq;     /* pointer to request structure */
    PINT_Request *rqbase; /* pointer to first request is sequence chain */
    int32_t blk;      /* number of block being processed */
    PVFS_offset  chunk_offset; /* offset of beginning of current contiguous
} PINT_reqstack;
```

```
typedef struct PINT_Request_state {
   struct PINT_reqstack *cur; /* request element chain stack */
   int32_t lvl;        /* level in element chain */
   PVFS_size    bytes;      /* bytes in current contiguous chunk processed
   PVFS_offset  buf_offset; /* byte offset in user buffer */
} PINT_Request_state;
```

The PINT_Request_state utilizes a stack to keep up with each level in the element type chain. For each level, a stack element records which block and which element within the block is being processed as well as which PVFS_Request record in the sequence chain is being processed. The maxel and dtbase fields are used to reset each level each time it is entered. The PINT_Request_state records the level being processed and a function used to process each contiguous block of data. The bytes field is used to record the results of a partial processing of bytes so the processing can be paused and resumed later.

4 PINT_Process_request interface

Requests and distributions are processed using the interface described here. The caller allocates an array of SEGMAX offsets and an array of SEGMAX segment sizes. These are passed to the PINT_Process_request function allong with an initialized PINT_Request_state, a PVFS_Request, a PVFS_Request_file_data struct which includes distribution, distribution parameters, metadata, and an EXTEND_FLAG that indicates if the routine should stop at the current end of file (if the value is zero) or should extend the local file to the size needed to complete the request (if the value is non-zero) in the even that the file ends before the end of the request. A read will typically have a zero value and a write will typically have a one value. Other arguments to PINT_Process_request include the maximum number of segments to process SEGMAX, a maximum number of bytes to transfer BYTEMAX, and a starting offset START_OFFSET, and EOF_FLAG argument returns whether the end of the request is at or beyond the end of file.

```
typedef struct PINT_Request_file_data {
   PVFS_size    fsize;     /* actual size of local storage object */
   int32_t server_nr;   /* ordinal number of THIS server for this file */
   int32_t server_ct; /* number of servers for this file */
   PVFS_Distribution *dist;
   PVFS_Dist_parm    *dparm;
   PVFS_boolean      extend_flag;
} PINT_Request_file_data;
```

PINT_Process_request fills in up to SEGMAX array entries, updates SEGMAX to indicate the number of segments processed, updates BYTEMAX to indicate the number of bytes processed, and updates

START_OFFSET and the PINT_Reqest_state to indicate the last point in the request procssed. The function attempts to process BYTEMAX bytes, but cannot process more than SEGMAX contiguous regions. The code is expected to be optimized for the case where START_OFFSET is equal to the value returned the last time the function was called with the same PINT_Request_state.

```
int PINT_Process_request(PINT_Request_state *req,
   PINT_Request_file_data *rfdata, int32_t *segmax,
   PVFS_offset *offset_array, PVFS_size *size_array,
   PVFS_offset *start_offset, PVFS_size *bytemax,
   PVFS_boolean *eof_flag, int mode);
```

The MODE tells the request processor whether to process the request in terms of the local file offsets on a server or local buffer offsets on a client. Clients should set this to PVFS_CLIENT to indicate that the data will be read into a contiguous buffer. Servers should set to PVFS_SERVER to indicate that the offsets computed by the distribution module should be used as the local file offsets. A third mode PVFS_CKSIZE indicates that the routine should count how many bytes up to BYTEMAX are left in the request, but does not alter the requset state or update the SIZE_ARRAY or OFFSET_ARRAY.

Before calling PINT_Process_request for a given request for the first time, the caller needs to allocate a PINT_Request_state structure. This is done by calling PINT_New_request passing in a pointer to the request. Theoretically multiple request states can exist for the same request, thought there is really no need to do such a thing.

```
struct PINT_Request_state *PINT_New_request_state (PINT_Request *request);
```

The new request state is positioned at the beginning of the request. The caller must also allocate a 64-bit start_offset, as well as the offset and size arrays, eof_flag, segmax, and bytemax. Each time PINT_Process_request is called, the segmax, bytemax, and eof_flag should be reset to the proper values, as the function returns results in these variables as well as taking inputs from them. The offset and size arrays are overwritten each time PINT_Process_state is called. The start_offset variable is normally NOT reset between calls as the caller normally wishes to continue translating the request from the point left off previously. After completing the processing of the request, the caller is also responsible for freeing the request state structure with a call to PINT_Free_request.

```
void PINT_Free_request_state (PINT_Request_state *req);
```

The following is a sample of code calling the request processing routines. It processes an entire request using no more than SEGMAX contiguous sements at a time and no more than BYTEMAX bytes at a time.

```
#include <pvfs-types.h>
#include <pint_distribution.h>

#define SEGMAX 32
#define BYTEMAX 250

do_a_request(PINT_Request *req,
      PVFS_Distribution *dist,
      PVFS_Dist_parm *dparm,
      PVFS_Meta meta)
{
   int i;

   // PVFS_Process_request arguments
   PINT_Request_state *reqs;
PINT_Request_file_data rfdata;
   PVFS_offset offset_array[SEGMAX];
   PVFS_size size_array[SEGMAX];
   PVFS_offset offset;
   PVFS_size bytemax;
   int32_t segmax;
   PVFS_boolean extend_flag;
   PVFS_boolean eof_flag;

   reqs = PINT_New_request_state(req);
   rfdata.server_nr = 0;
   rfdata.server_ct = 1;
   rfdata.fsize = 10000000;
   rfdata.dist = dist
   rfdata.dparm = dparm
   rfdata.extend_flag = 0;
   eof_flag = 0;
   offset = 0;
   do {
      segmax = SEGMAX;
      bytemax = BYTEMAX;
      PINT_Process_request(reqs, &rfdata, &segmax, offset_array,
            size_array, &offset, &bytemax, &eof_flag, PINT_SERVER);
      printf("processed %lld bytes in %d segments\n", bytemax, segmax);
      for (i = 0; i < segmax; i++)
      {
         printf("segment %d: offset=%lld size=%lld\n", i,
               offset_array[i], size_array[i]);
```

```
        }
    } while (offset != -1);
}
```