OpenSHMEM

Application Programming Interface

http://www.openshmem.org/

Version 1.3

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Contents

1 The OpenSHMEM Effort

OpenSHMEM is a *Partitioned Global Address Space* (PGAS) library interface specification. OpenSHMEM aims to provide a standard *Application Programming Interface* (API) for SHMEM libraries to aid portability and facilitate uniform predictable results of OpenSHMEM programs by explicitly stating the behavior and semantics of the OpenSHMEM library calls. Through the different versions, OpenSHMEM will continue to address the requirements of the PGAS community. As of this specification, existing vendors are moving towards OpenSHMEM compliant implementations and new vendors are developing OpenSHMEM library implementations to help the users write portable OpenSHMEM code. This ensures that programs can run on multiple platforms without having to deal with subtle vendor-specific implementation differences. For more details on the history of OpenSHMEM please refer to the History of OpenSHMEM section.

The OpenSHMEM[1] effort is driven by the Extreme Scale Systems Center (ESSC) at ORNL and the University of Houston with significant input from the OpenSHMEM community. Besides the specification, the effort also includes providing a reference OpenSHMEM implementation, validation and verification suites, tools, a mailing list and website infrastructure to support specification activities. For more information please refer to: `http://www.openshmem.org/`.

2 Programming Model Overview

OpenSHMEM implements PGAS by defining remotely accessible data objects as mechanisms to share information among OpenSHMEM processes or *Processing Elements* (PEs) and private data objects that are accessible by the PE itself. The API allows communication and synchronization operations on both private (local to the PE initiating the operation) and remotely accessible data objects. The key feature of OpenSHMEM is that data transfer operations are ***one-sided*** in nature. This means that a local PE executing a data transfer routine does not require the participation of the remote PE to complete the routine. This allows for overlap between communication and computation to hide data transfer latencies, which makes OpenSHMEM ideal for unstructured, small/medium size data communication patterns. The OpenSHMEM library routines have the potential to provide a low-latency, high-bandwidth communication API for use in highly parallelized scalable programs.

The OpenSHMEM interfaces can be used to implement *Single Program Multiple Data* (SPMD) style programs. It provides interfaces to start the OpenSHMEM PEs in parallel, and communication and synchronization interfaces to access remotely accessible data objects across PEs. These interfaces can be leveraged to divide a problem into multiple sub-problems that can be solved independently or with coordination using the communication and synchronization interfaces. The OpenSHMEM specification defines library calls, constants, variables, and language bindings for *C* and *Fortran*. The *C++* interface is currently the same as that for *C*. Unlike UPC, Fortran 2008, Titanium, X10 and Chapel, which are all PGAS languages, OpenSHMEM relies on the user to use the library calls to implement the correct semantics of its programming model.

An overview of the OpenSHMEM routines is described below:

1. **Library Setup and Query**
   (a) *Initialization*: The OpenSHMEM library environment is initialized.
   (b) *Query*: The local PE may get the number of PEs running the same program and its unique integer identifier.
   (c) *Accessibility*: The local PE can find out if a remote PE is executing the same binary, or if a particular symmetric data object can be accessed by a remote PE, or may obtain a pointer to a symmetric data object on the specified remote PE on shared memory systems.
2. **Symmetric Data Object Management**
   (a) *Allocation*: All executing PEs must participate in the allocation of a symmetric data object with identical arguments.

[1] The OpenSHMEM specification is owned by Open Source Software Solutions Inc., a non-profit organization, under an agreement with SGI.

(b) *Deallocation*: All executing PEs must participate in the deallocation of the same symmetric data object with identical arguments.

(c) *Reallocation*: All executing PEs must participate in the reallocation of the same symmetric data object with identical arguments.

3. **Remote Memory Access**

   (a) *Put*: The local PE specifies the *source* data object (private or symmetric) that is copied to the symmetric data object on the remote PE.

   (b) *Get*: The local PE specifies the symmetric data object on the remote PE that is copied to a data object (private or symmetric) on the local PE.

4. **Atomics**

   (a) *Swap*: The PE initiating the swap gets the old value of a symmetric data object from a remote PE and copies a new value to that symmetric data object on the remote PE.

   (b) *Increment*: The PE initiating the increment adds 1 to the symmetric data object on the remote PE.

   (c) *Add*: The PE initiating the add specifies the value to be added to the symmetric data object on the remote PE.

   (d) *Compare and Swap*: The PE initiating the swap gets the old value of the symmetric data object based on a value to be compared and copies a new value to the symmetric data object on the remote PE.

   (e) *Fetch and Increment*: The PE initiating the increment adds 1 to the symmetric data object on the remote PE and returns with the old value.

   (f) *Fetch and Add*: The PE initiating the add specifies the value to be added to the symmetric data object on the remote PE and returns with the old value.

5. **Synchronization and Ordering**

   (a) *Fence*: The PE calling fence ensures ordering of *Put*, AMO, and memory store operations to symmetric data objects with respect to a specific destination PE.

   (b) *Quiet*: The PE calling quiet ensures completion of remote access operations and stores to symmetric data objects.

   (c) *Barrier*: All or some PEs collectively synchronize and ensure completion of all remote and local updates prior to any PE returning from the call.

6. **Collective Communication**

   (a) *Broadcast*: The *root* PE specifies a symmetric data object to be copied to a symmetric data object on one or more remote PEs (not including itself).

   (b) *Collection*: All PEs participating in the routine get the result of concatenated symmetric objects contributed by each of the PEs in another symmetric data object.

   (c) *Reduction*: All PEs participating in the routine get the result of an associative binary routine over elements of the specified symmetric data object on another symmetric data object.

7. **Mutual Exclusion**

   (a) *Set Lock*: The PE acquires exclusive access to the region bounded by the symmetric *lock* variable.

   (b) *Test Lock*: The PE tests the symmetric *lock* variable for availability.

   (c) *Clear Lock*: The PE which has previously acquired the *lock* releases it.

8. **Data Cache Control** ***(deprecated)***

   (a) Implementation of mechanisms to exploit the capabilities of hardware cache if available.

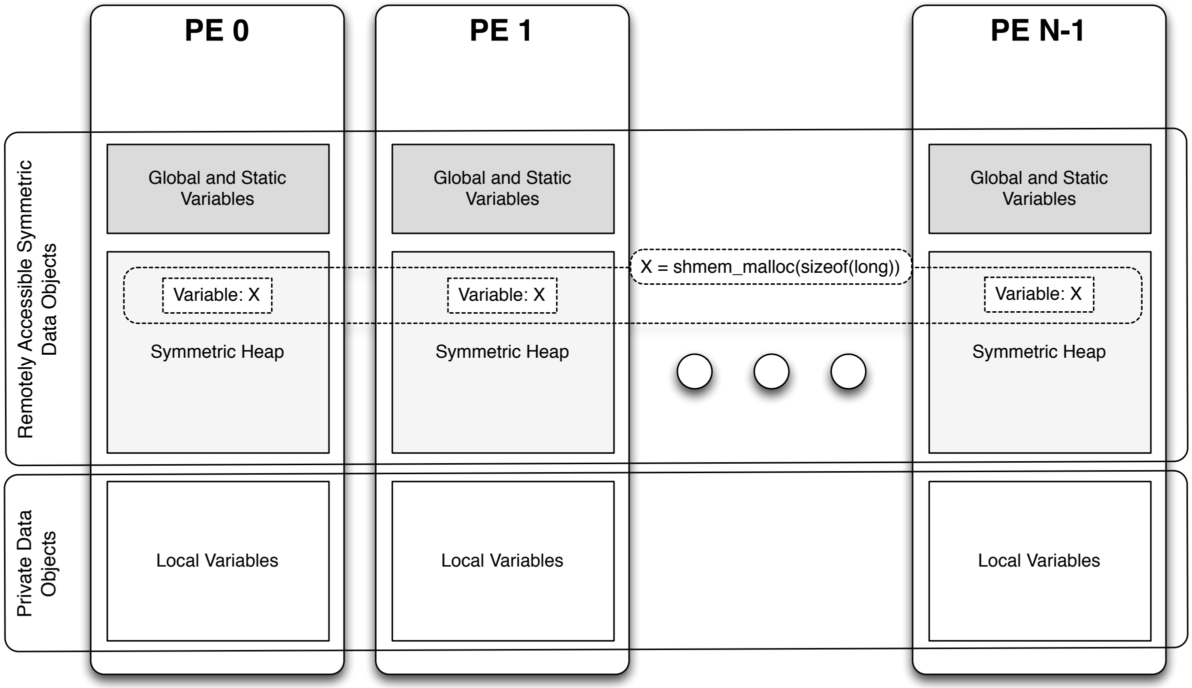


Figure 1: *OpenSHMEM* Memory Model

3 Memory Model

An OpenSHMEM program consists of data objects that are private to each PE and data objects that are remotely accessible by all PEs. Private data objects are stored in the local memory of each PE and can only be accessed by the PE itself; these data objects cannot be accessed by other PEs via OpenSHMEM routines. Private data objects follow the memory model of *C* or *Fortran*. Remotely accessible objects, however, can be accessed by remote PEs using OpenSHMEM routines. Remotely accessible data objects are called *Symmetric Data Objects*. Each symmetric data object has a corresponding object with the same name, type, and size on all PEs where that object is accessible via the OpenSHMEM API[2]. (For the definition of what is accessible, see the descriptions for *shmem_pe_accessible* and *shmem_addr_accessible* in sections 8.1.6 and 8.1.7.) Symmetric data objects accessed via typed OpenSHMEM interfaces are required to be natural aligned based on their type requirements and underlying architecture. In OpenSHMEM the following kinds of data objects are symmetric:

- *Fortran* data objects in common blocks or with the SAVE attribute. These data objects must not be defined in a dynamic shared object (DSO).
- Global and static *C* and *C++*variables. These data objects must not be defined in a DSO.
- *Fortran* arrays allocated with *shpalloc*
- *C* and *C++*data allocated by *shmem_malloc*

OpenSHMEM dynamic memory allocation routines (*shpalloc* and *shmem_malloc*) allow collective allocation of *Symmetric Data Objects* on a special memory region called the *Symmetric Heap*. The Symmetric Heap is created during the execution of a program at a memory location determined by the implementation. The Symmetric Heap may reside in different memory regions on different PEs. Figure 1 shows how OpenSHMEM implements a PGAS model using remotely accessible symmetric objects and private data objects when executing an OpenSHMEM program. Symmetric data objects are stored on the symmetric heap or in the global/static memory section of each PE.

[2]For efficiency reasons, the same offset (from an arbitrary memory address) for symmetric data objects might be used on all PEs. Further discussion about symmetric heap layout and implementation efficiency can be found in section 8.2.1

4 Execution Model

An OpenSHMEM program consists of a set of OpenSHMEM processes called PEs that execute in a SPMD-like model where each PE can take a different execution path. For example, a PE can be implemented using an OS process. The PEs progress asynchronously, and can communicate/synchronize via the OpenSHMEM interfaces. All PEs in an OpenSHMEM program should start by calling the initialization routine *shmem_init* [3] before using any of the other OpenSHMEM library routines. An OpenSHMEM program finishes execution by returning from the main routine or when any PE calls *shmem_global_exit*. When returning from main, OpenSHMEM must complete all pending communication and release all the resources associated to the library using an implicit collective synchronization across PEs. The user has the option to call *shmem_finalize* (before returning from main) to complete all pending communication and release all the OpenSHMEM library resources without terminating the program. Calling any OpenSHMEM routine after *shmem_finalize* leads to undefined behavior.

The PEs of the OpenSHMEM program are identified by unique integers. The identifiers are integers assigned in a monotonically increasing manner from zero to the total number of PEs minus 1. PE identifiers are used for OpenSHMEM calls (e.g. to specify *put* or *get* routines on symmetric data objects, collective synchronization calls) or to dictate a control flow for PEs using constructs of *C* or *Fortran*. The identifiers are fixed for the life of the OpenSHMEM program.

4.1 Progress of OpenSHMEM Operations

The OpenSHMEM model assumes that computation and communication are naturally overlapped. OpenSHMEM programs are expected to exhibit progression of communication both with and without OpenSHMEM calls. Consider a PE that is engaged in a computation with no OpenSHMEM calls. Other PEs should be able to communicate (*put*, *get*, *collective*, *atomic*, etc) and complete communication operations with that computationally-bound PE without that PE issuing any explicit OpenSHMEM calls. OpenSHMEM communication calls involving that PE should progress regardless of when that PE next engages in an OpenSHMEM call.

Note to implementors:

- An OpenSHMEM implementation for hardware that does not provide asynchronous communication capabilities may require a software progress thread in order to process remotely-issued communication requests without explicit program calls to the OpenSHMEM library.

- High performance implementations of OpenSHMEM are expected to leverage hardware offload capabilities and provide asynchronous one-sided communication without software assistance.

- Implementations should avoid deferring the execution of one-sided operations until a synchronization point where data is known to be available. High-quality implementations should attempt asynchronous delivery whenever possible, for performance reasons. Additionally, the OpenSHMEM community discourages releasing OpenSHMEM implementations that do not provide asynchronous one-sided operations, as these have very limited performance value for OpenSHMEM programs.

4.2 Atomicity Guarantees

OpenSHMEM contains a number of routines that operate on symmetric data atomically (Section 8.5). These routines guarantee that accesses by OpenSHMEM's atomic operations with the same datatype will be exclusive, but do not guarantee exclusivity in combination with other routines, either inside OpenSHMEM or outside.

For example: during the execution of an atomic remote integer increment operation on a symmetric variable *X*, no other OpenSHMEM atomic operation may access *X*. After the increment, *X* will have increased its value by *1* on the destination PE, at which point other atomic operations may then modify that *X*. However, access to the symmetric object *X* with non-atomic operations, such as one-sided *put* or *get* operations, will *invalidate* the atomicity guarantees.

[3] **start_pes** has been deprecated as of Specification 1.2

5 Language Bindings and Conformance

OpenSHMEM provides ISO *C* and *Fortran 90* language bindings. Any implementation that provides both *C* and *Fortran* bindings can claim conformance to the specification. An implementation that provides e.g. only a *C* interface may claim to conform to the OpenSHMEM specification with respect to the *C* language, but not to *Fortran*, and should make this clear in its documentation. The OpenSHMEM header files for *C* and *Fortran* must contain only the interfaces and constant names defined in this specification.

OpenSHMEM APIs can be implemented as either routines or macros. However, implementing the interfaces using macros is strongly discouraged as this could severely limit the use of external profiling tools and high-level compiler optimizations. An OpenSHMEM program should avoid defining routine names, variables, or identifiers with the prefix *SHMEM_*(for *C* and *Fortran*), *_SHMEM_*(for *C*) or with OpenSHMEM API names.

All OpenSHMEM extension APIs that are not part of this specification must be defined in the *shmemx.h* include file. These extensions shall use the *shmemx_* prefix for all routine, variable, and constant names.

6 Library Constants

The constants that start with SHMEM_* are for both *Fortran* and *C/C++*, and they are compile-time constants. All constants that start with _SHMEM_* are deprecated and provided for backwards compatibility.

Constant	**Description**
C/C++/Fortran: SHMEM_BCAST_SYNC_SIZE	Length of the *pSync* arrays needed for broadcast routines. The value of this constant is implementation specific. Refer to the Broadcast Routines section under Library Routines for more information about the usage of this constant.
C/C++/Fortran: SHMEM_SYNC_VALUE	The value used to initialize the elements of *pSync* arrays. The value of this constant is implementation specific.
C/C++/Fortran: SHMEM_REDUCE_SYNC_SIZE	Length of the work arrays needed for reduction routines. The value of this constant is implementation specific. Refer to the Reduction Routines section under Library Routines for more information about the usage of this constant.
C/C++/Fortran: SHMEM_BARRIER_SYNC_SIZE	Length of the work array needed for barrier routines. The value of this constant is implementation specific. Refer to the Barrier Synchronization Routines section under Library Routines for more information about the usage of this constant.
C/C++/Fortran: SHMEM_COLLECT_SYNC_SIZE	Length of the work array needed for collect routines. The value of this constant is implementation specific. Refer to the Collect Routines section under Library Routines for more information about the usage of this constant.
C/C++/Fortran: SHMEM_ALLTOALL_SYNC_SIZE	Length of the work array needed for *shmem_alltoall* routines. The value of this constant is implementation specific. Refer to the Alltoall routines sections under Library Routines for more information about the usage of this constant.

C/C++/Fortran: SHMEM_ALLTOALLS_SYNC_SIZE	Length of the work array needed for *shmem_alltoalls* routines. The value of this constant is implementation specific. Refer to the Alltoalls routines sections under Library Routines for more information about the usage of this constant.
C/C++/Fortran: SHMEM_REDUCE_MIN_WRKDATA_SIZE	Minimum length of work arrays used in various collective routines.
C/C++/Fortran: SHMEM_MAJOR_VERSION	Integer representing the major version of OpenSHMEM standard in use.
C/C++/Fortran: SHMEM_MINOR_VERSION	Integer representing the minor version of OpenSHMEM standard in use.
C/C++/Fortran: SHMEM_MAX_NAME_LEN	Integer representing the length of vendor string.
C/C++/Fortran: SHMEM_VENDOR_STRING	String representing the vendor name of length less than SHMEM_MAX_NAME_LEN. In Fortran the string must be SHMEM_MAX_NAME_LEN and whitespace padded. It can also be equal in length to SHMEM_MAX_NAME_LEN since Fortran does not NULL terminate strings.

7 Environment Variables

The OpenSHMEM specification provides a set of environment variables that allows users to configure the OpenSHMEM implementation, and receive information about the implementation. The implementations of the specification are free to define additional variables. Currently, the specification defines four environment variables.

Variable	Value	Purpose
`SMA_VERSION`	any	print the library version at start-up
`SMA_INFO`	any	print helpful text about all these environment variables
`SMA_SYMMETRIC_SIZE`	non-negative integer	number of bytes to allocate for symmetric heap
`SMA_DEBUG`	any	enable debugging messages

8 OpenSHMEM Library API

8.1 Library Setup, Exit, and Query Routines

The library setup and query interfaces that initialize and monitor the parallel environment of the PEs.

8.1.1 SHMEM_INIT

A collective operation that allocates and initializes the resources used by the OpenSHMEM library.

SYNOPSIS

C/C++:

```
void shmem_init(void);
```

FORTRAN:

```
CALL SHMEM_INIT()
```

DESCRIPTION

Arguments

None.

API description

shmem_init allocates and initializes resources used by the OpenSHMEM library. It is a collective operation that all PEs must call before any other OpenSHMEM routine may be called. At the end of the OpenSHMEM program which it initialized, the call to *shmem_init* must be matched with a call to *shmem_finalize*. After the first call to *shmem_init*, a subsequent call to *shmem_init* in the same program results in undefined behavior.

Return Values

None.

Notes

As of OpenSHMEM Specification 1.2 the use of *start_pes* has been deprecated and is replaced with *shmem_init*. While support for *start_pes* is still required in OpenSHMEM libraries, users are encouraged to use *shmem_init*. Replacing *start_pes* with *shmem_init* in OpenSHMEM programs with no further changes is possible; there is an implicit *shmem_finalize* at the end of main. However, *shmem_init* differs slightly from *start_pes*: multiple calls to *shmem_init* within a program results in undefined behavior, while in the case of *start_pes*, any subsequent calls to *start_pes* after the first one resulted in a no-op.

EXAMPLES

This is a simple program that calls *shmem_init*:

```
PROGRAM PUT
INCLUDE "shmem.fh"

INTEGER TARG, SRC, RECEIVER, BAR
COMMON /T/ TARG
PARAMETER (RECEIVER=1)
CALL SHMEM_INIT()

IF (SHMEM_MY_PE() .EQ. 0) THEN
```

```
    SRC = 33
    CALL SHMEM_INTEGER_PUT(TARG, SRC, 1, RECEIVER)
ENDIF

CALL SHMEM_BARRIER_ALL           ! SYNCHRONIZES SENDER AND RECEIVER

IF (SHMEM_MY_PE() .EQ. RECEIVER) THEN
    PRINT*,'PE ', SHMEM_MY_PE(),' TARG=',TARG,' (expect 33)'
ENDIF

CALL SHMEM_FINALIZE()

END
```

8.1.2 SHMEM_MY_PE

Returns the number of the calling PE.

SYNOPSIS

C/C++:

```
int shmem_my_pe(void);
```

FORTRAN:

```
INTEGER SHMEM_MY_PE, ME
ME = SHMEM_MY_PE()
```

DESCRIPTION

Arguments

None.

API description

This routine returns the PE number of the calling PE. It accepts no arguments. The result is an integer between *0* and *npes* - *1*, where *npes* is the total number of PEs executing the current program.

Return Values

Integer - Between *0* and *npes* - *1*

Notes

Each PE has a unique number or identifier. As of OpenSHMEM Specification 1.2 the use of *_my_pe* has been deprecated. Although OpenSHMEM libraries are required to support the call, users are encouraged to use *shmem_my_pe* instead. The behavior and signature of the routine *shmem_my_pe* remains unchanged from the deprecated *_my_pe* version.

EXAMPLES

The following *shmem_my_pe* example is for *C/C++* programs:

```
#include <stdio.h>
#include <shmem.h>

int main(void)
{
  int me;
```

```
  shmem_init();
  me = shmem_my_pe();
  printf("My PE id is: %d\n", me);

  return 0;
}
```

8.1.3 SHMEM_N_PES

Returns the number of PEs running in a program.

SYNOPSIS

C/C++:

```
int shmem_n_pes(void);
```

FORTRAN:

```
INTEGER SHMEM_N_PES, N_PES
N_PES = SHMEM_N_PES()
```

DESCRIPTION

Arguments

None.

API description

The routine returns the number of PEs running in the program.

Return Values

Integer - Number of PEs running in the OpenSHMEM program.

Notes

As of OpenSHMEM Specification 1.2 the use of *_num_pes* has been deprecated. Although OpenSHMEM libraries are required to support the call, users are encouraged to use *shmem_n_pes* instead. The behavior and signature of the routine *shmem_n_pes* remains unchanged from the deprecated *_num_pes* version.

EXAMPLES

The following *shmem_n_pes* example is for *C/C++* programs:

```
#include <stdio.h>
#include <shmem.h>

int main(void)
{
  int npes;

  shmem_init();

  npes = shmem_n_pes();

  if (shmem_my_pe() == 0) {
    printf("Number of PEs executing this program is: %d\n", npes);
  }

  return 0;
}
```

8.1.4 SHMEM_FINALIZE

A collective operation that releases resources used by the OpenSHMEM library. This only terminates the OpenSHMEM portion of a program, not the entire program.

SYNOPSIS

C/C++:

```
void shmem_finalize(void);
```

FORTRAN:

```
CALL SHMEM_FINALIZE()
```

DESCRIPTION

Arguments

None.

API description

shmem_finalize is a collective operation that ends the OpenSHMEM portion of a program previously initialized by *shmem_init* and releases resources used by the OpenSHMEM library. This collective operation requires all PEs to participate in the call. There is an implicit global barrier in *shmem_finalize* so that pending communications are completed, and no resources can be released until all PEs have entered *shmem_finalize*. *shmem_finalize* must be the last OpenSHMEM library call encountered in the OpenSHMEM portion of a program. A call to *shmem_finalize* will release any resources initialized by a corresponding call to *shmem_init*. All processes that represent the PEs will still exist after the call to *shmem_finalize* returns, but they will no longer have access to any resources that have been released.

Return Values

None.

Notes

shmem_finalize releases all resources used by the OpenSHMEM library including the symmetric memory heap and pointers initiated by *shmem_ptr*. This collective operation requires all PEs to participate in the call, not just a subset of the PEs. The non-OpenSHMEM portion of a program may continue after a call to *shmem_finalize* by all PEs. There is an implicit *shmem_finalize* at the end of main, so that having an explicit call to *shmem_finalize* is optional. However, an explicit *shmem_finalize* may be required as an entry point for wrappers used by profiling or other tools that need to perform their own finalization.

EXAMPLES

The following finalize example is for *C/C++* programs:

```
#include <stdio.h>
#include <shmem.h>

long x = 10101;

int main(void) {
   int me, npes;
   long y = -1;

   shmem_init();

   me = shmem_my_pe();
```

```
    npes = shmem_n_pes();
    if (me == 0)
      y = shmem_long_g(&x, npes-1);

    printf("%d: y = %ld\n", me, y);

    shmem_finalize();
    return 0;
}
```

8.1.5 SHMEM_GLOBAL_EXIT

A routine that allows any PE to force termination of an entire program.

SYNOPSIS

C/C++:

```
void shmem_global_exit(int status);
```

FORTRAN:

```
INTEGER STATUS
CALL SHMEM_GLOBAL_EXIT(status)
```

DESCRIPTION

Arguments

IN	*status*	The exit status from the main program.

API description

shmem_global_exit is a non-collective routine that allows any one PE to force termination of an OpenSHMEM program for all PEs, passing an exit status to the execution environment. This routine terminates the entire program, not just the OpenSHMEM portion. When any PE calls *shmem_global_exit*, it results in the immediate notification to all PEs to terminate. *shmem_global_exit* flushes I/O and releases resources in accordance with C/C++/Fortran language requirements for normal program termination. If more than one PE calls *shmem_global_exit*, then the exit status returned to the environment shall be one of the values passed to *shmem_global_exit* as the status argument. There is no return to the caller of *shmem_global_exit*; control is returned from the OpenSHMEM program to the execution environment for all PEs.

Return Values

None.

Notes

shmem_global_exit may be used in situations where one or more PEs have determined that the program has completed and/or should terminate early. Accordingly, the integer status argument can be used to pass any information about the nature of the exit, e.g an encountered error or a found solution. Since *shmem_global_exit* is a non-collective routine, there is no implied synchronization, and all PEs must terminate regardless of their current execution state. While I/O must be flushed for standard language I/O calls from C/C++/Fortran, it is implementation dependent as to how I/O done by other means (e.g. third party I/O libraries) is handled. Similarly, resources are released according to C/C++/Fortran standard language requirements, but this may not include all resources allocated for the OpenSHMEM program. However, a quality implementation will make a best effort to flush all I/O and clean up all resources.

EXAMPLES

```c
#include <stdio.h>
#include <stdlib.h>
#include <shmem.h>

int
main(void)
{
  int me, npes;

  shmem_init();

  me = shmem_my_pe();
  npes = shmem_n_pes();

  if (me == 0) {
    FILE *fp = fopen("input.txt", "r");

    if (fp == NULL) {  /* Input file required by program is not available */
      shmem_global_exit(EXIT_FAILURE);
    }

    /* do something with the file */

    fclose(fp);
  }

  return 0;
}
```

8.1.6 SHMEM_PE_ACCESSIBLE

Determines whether a PE is accessible via OpenSHMEM's data transfer routines.

SYNOPSIS

C/C++:

```c
int shmem_pe_accessible(int pe);
```

FORTRAN:

```fortran
LOGICAL LOG, SHMEM_PE_ACCESSIBLE
INTEGER pe
LOG = SHMEM_PE_ACCESSIBLE(pe)
```

DESCRIPTION

Arguments

IN	*pe*	Specific PE to be checked for accessibility from the local PE.

API description

shmem_pe_accessible is a query routine that indicates whether a specified PE is accessible via OpenSHMEM from the local PE. The *shmem_pe_accessible* routine returns *TRUE* only if the remote PE is a process running from the same executable file as the local PE, indicating that full OpenSHMEM support for symmetric data objects (that reside in the static memory and symmetric heap) is available, otherwise it returns *FALSE*. This routine may be particularly useful for hybrid programming with other communication libraries (such as a MPI) or parallel languages. For example, on SGI Altix series systems, OpenSHMEM is supported across multiple partitioned hosts and InfiniBand connected hosts. When running multiple executable MPI programs using OpenSHMEM on an Altix, full OpenSHMEM support is available between processes running from the same executable file. However, OpenSHMEM support between processes of different executable files is supported only for data objects on the symmetric heap, since static data objects are not symmetric between different executable files.

Return Values

C/C++: The return value is 1 if the specified PE is a valid remote PE for OpenSHMEM routines; otherwise, it is 0.

Fortran: The return value is *.TRUE.* if the specified PE is a valid remote PE for OpenSHMEM routines; otherwise, it is *.FALSE.*.

Notes

None.

8.1.7 SHMEM_ADDR_ACCESSIBLE

Determines whether an address is accessible via OpenSHMEM data transfer routines from the specified remote PE.

SYNOPSIS

C/C++:

```
int shmem_addr_accessible(const void *addr, int pe);
```

FORTRAN:

```
LOGICAL LOG, SHMEM_ADDR_ACCESSIBLE
INTEGER pe
LOG = SHMEM_ADDR_ACCESSIBLE(addr, pe)
```

DESCRIPTION

Arguments

IN	*addr*	Data object on the local PE.
IN	*pe*	Integer id of a remote PE.

API description

shmem_addr_accessible is a query routine that indicates whether a local address is accessible via OpenSHMEM routines from the specified remote PE.

This routine verifies that the data object is symmetric and accessible with respect to a remote PE via OpenSHMEM data transfer routines. The specified address *addr* is a data object on the local PE.

This routine may be particularly useful for hybrid programming with other communication libraries (such as MPI) or parallel languages. For example, in SGI Altix series systems, for multiple executable MPI programs that use OpenSHMEM routines, it is important to note that static memory, such as a *Fortran* common block or *C* global variable, is symmetric between processes running from the same executable file, but is not symmetric between processes running from different executable files. Data allocated from the symmetric heap (*shmem_malloc* or *shpalloc*) is symmetric across the same or different executable files.

Return Values

C/C++: The return value is *1* if *addr* is a symmetric data object and accessible via OpenSHMEM routines from the specified remote PE; otherwise, it is *0*.

Fortran: The return value is *.TRUE.* if *addr* is a symmetric data object and accessible via OpenSHMEM routines from the specified remote PE; otherwise, it is *.FALSE.*.

Notes

None.

8.1.8 SHMEM_PTR

Returns a pointer to a data object on a specified PE.

SYNOPSIS

C/C++:

```
void *shmem_ptr(const void *dest, int pe);
```

FORTRAN:

```
POINTER (PTR, POINTEE)
INTEGER pe
PTR = SHMEM_PTR(dest, pe)
```

DESCRIPTION

Arguments

IN	*dest*	The symmetric data object to be referenced.
IN	*pe*	An integer that indicates the PE number on which *dest* is to be accessed. If you are using *Fortran*, it must be a default integer value.

API description

shmem_ptr returns an address that may be used to directly reference *dest* on the specified PE. This address can be assigned to a pointer. After that, ordinary loads and stores to this remote address may be performed.

When a sequence of loads (gets) and stores (puts) to a data object on a remote PE does not match the access pattern provided in an OpenSHMEM data transfer routine like *shmem_put32* or *shmem_real_iget*, the *shmem_ptr* routine can provide an efficient means to accomplish the communication.

Return Values

The return value is a non-NULL address of the *dest* data object when it is accessible using memory loads and stores in addition to OpenSHMEM operations. Otherwise, a NULL address is returned.

Notes

When calling *shmem_ptr*, *dest* is the address of the referenced symmetric data object on the calling PE.

EXAMPLES

This *Fortran* program calls *shmem_ptr* and then PE 0 writes to the *BIGD* array on PE 1:

```
PROGRAM REMOTEWRITE
INCLUDE "shmem.fh"

INTEGER BIGD(100)
SAVE BIGD

INTEGER POINTEE(*)
POINTER (PTR,POINTEE)
```

```
CALL SHMEM_INIT()


IF (SHMEM_MY_PE() .EQ. 0) THEN
   ! initialize PE 1's BIGD array
   PTR = SHMEM_PTR(BIGD, 1)      ! get address of PE 1's BIGD
                                 !   array
   DO I=1,100
        POINTEE(I) = I
   ENDDO
ENDIF

CALL SHMEM_BARRIER_ALL

IF (SHMEM_MY_PE() .EQ. 1) THEN
   PRINT*,'BIGD on PE 1 is: '
   PRINT*,BIGD
ENDIF
END
```

This is the equivalent program written in *C*:

```
#include <stdio.h>
#include <shmem.h>

int main(void)
{
   static int bigd[100];
      int *ptr;
      int i;

   shmem_init();

   if (shmem_my_pe() == 0) {
      /* initialize PE 1's bigd array */
      ptr = shmem_ptr(bigd, 1);
      if (ptr == NULL)
         printf("can't use pointer to directly access PE 1's array\n");
      else
         for (i=0; i<100; i++)
            *ptr++ = i+1;
   }

   shmem_barrier_all();

   if (shmem_my_pe() == 1) {
      printf("bigd on PE 1 is:\n");
      for (i=0; i<100; i++)
         printf(" %d\n",bigd[i]);
      printf("\n");
   }
  return 1;
}
```

8.1.9 SHMEM_INFO_GET_VERSION

Returns the major and minor version of the library implementation.

SYNOPSIS

C/C++:

```
void shmem_info_get_version(int *major, int *minor);
```

FORTRAN:

```
INTEGER MAJOR, MINOR
SHMEM_INFO_GET_VERSION(MAJOR, MINOR)
```

DESCRIPTION

Arguments

OUT	*major*	The major version of the OpenSHMEM standard in use.
OUT	*minor*	The minor version of the OpenSHMEM standard in use.

API description

This routine returns the major and minor version of the OpenSHMEM standard in use. For a given library implementation, the major and minor version returned by these calls is consistent with the compile-time constants, SHMEM_MAJOR_VERSION and SHMEM_MINOR_VERSION, defined in its shmem.h.

Return Values

None.

Notes

None.

8.1.10 SHMEM_INFO_GET_NAME

This routine returns the vendor defined character string.

SYNOPSIS

C/C++:

```
void shmem_info_get_name(char *name);
```

FORTRAN:

```
CHARACTER *(*)NAME
SHMEM_INFO_GET_NAME(NAME)
```

DESCRIPTION

Arguments

OUT	*name*	The vendor defined string.

API description

This routine returns the vendor defined character string of size defined by the constant SHMEM_MAX_NAME_LEN. The program calling this function prepares the memory of size SHMEM_MAX_NAME_LEN, and the implementation copies the string of size at most SHMEM_MAX_NAME_LEN. In C, the string is terminated by a null character. In Fortran, the string of size less than SHMEM_MAX_NAME_LEN is padded with blank characters up to size SHMEM_MAX_NAME_LEN. The implementation copying a string of size greater than SHMEM_MAX_NAME_LEN results in an undefined behavior. Multiple invocations of the routine in an OpenSHMEM program always return the same string. For a given library implementation, the major and minor version returned by these calls is consistent with the compile-time constants defined in its shmem.h.

Return Values
None.

Notes
None.

8.1.11 START_PES

Called at the beginning of an OpenSHMEM program to initialize the execution environment. This routine is deprecated and is provided for backwards compatibility. Implementations must include it, and the routine should function properly and may notify the user about deprecation of its use.

SYNOPSIS

C/C++:

```
void start_pes(int npes);
```

FORTRAN:

```
CALL START_PES(npes)
```

DESCRIPTION

Arguments

npes	*Unused*	Should be set to *0*.

API description
The *start_pes* routine initializes the OpenSHMEM execution environment. An OpenSHMEM program must call *start_pes* before calling any other OpenSHMEM routine.

Return Values
None.

Notes
If any other OpenSHMEM call occurs before *start_pes*, the behavior is undefined. Although it is recommended to set *npes* to *0* for *start_pes*, this is not mandated. The value is ignored. Calling *start_pes* more than once has no subsequent effect.

As of OpenSHMEM Specification 1.2 the use of *start_pes* has been deprecated. Although OpenSHMEM libraries are required to support the call, program users are encouraged to use *shmem_init* instead.

EXAMPLES

This is a simple program that calls *start_pes*:

```
PROGRAM PUT
INCLUDE "shmem.fh"

INTEGER TARG, SRC, RECEIVER, BAR
COMMON /T/ TARG
PARAMETER (RECEIVER=1)
CALL START_PES(0)

IF (SHMEM_MY_PE() .EQ. 0) THEN
    SRC = 33
```

```
    CALL SHMEM_INTEGER_PUT(TARG, SRC, 1, RECEIVER)
ENDIF

CALL SHMEM_BARRIER_ALL           ! SYNCHRONIZES SENDER AND RECEIVER

IF (SHMEM_MY_PE() .EQ. RECEIVER) THEN
    PRINT*,'PE ', SHMEM_MY_PE(),' TARG=',TARG,' (expect 33)'
ENDIF
END
```

8.2 Memory Management Routines

OpenSHMEM provides a set of APIs for managing the symmetric heap. The APIs allow one to dynamically allocate, deallocate, reallocate and align symmetric data objects in the symmetric heap, in *C* and *Fortran*.

8.2.1 SHMEM_MALLOC, SHMEM_FREE, SHMEM_REALLOC, SHMEM_ALIGN

Symmetric heap memory management routines.

SYNOPSIS

C/C++:

```
void *shmem_malloc(size_t size);
void shmem_free(void *ptr);
void *shmem_realloc(void *ptr, size_t size);
void *shmem_align(size_t alignment, size_t size);
```

DESCRIPTION

Arguments

IN	*size*	The size, in bytes, of a block to be allocated from the symmetric heap. This argument is of type *size_t*
IN	*ptr*	Points to a block within the symmetric heap.
IN	*alignment*	Byte alignment of the block allocated from the symmetric heap.

API description

The *shmem_malloc* routine returns a pointer to a block of at least *size* bytes suitably aligned for any use. This space is allocated from the symmetric heap (in contrast to *malloc*, which allocates from the private heap).

The *shmem_align* routine allocates a block in the symmetric heap that has a byte alignment specified by the alignment argument.

The *shmem_free* routine causes the block to which *ptr* points to be deallocated, that is, made available for further allocation. If *ptr* is a null pointer, no action occurs.

The *shmem_realloc* routine changes the size of the block to which *ptr* points to the size (in bytes) specified by *size*. The contents of the block are unchanged up to the lesser of the new and old sizes. If the new size is larger, the newly allocated portion of the block is uninitialized. If *ptr* is a *NULL* pointer, the *shmem_realloc* routine behaves like the *shmem_malloc* routine for the specified size. If *size* is *0* and *ptr* is not a *NULL* pointer, the block to which it points is freed. If the space cannot be allocated, the block to which *ptr* points is unchanged.

The *shmem_malloc*, *shmem_free*, and *shmem_realloc* routines are provided so that multiple PEs in a program can allocate symmetric, remotely accessible memory blocks. These memory blocks can then be used with OpenSHMEM communication routines. Each of these routines call the *shmem_barrier_all* routine before returning; this ensures that all PEs participate in the memory allocation, and that the memory on other PEs can be used as soon as the local PE returns. The user is responsible for calling these routines with identical argument(s) on all PEs; if differing *size* arguments are used, the behavior of the call and any subsequent OpenSHMEM calls becomes undefined.

Return Values

The *shmem_malloc* routine returns a pointer to the allocated space; otherwise, it returns a *NULL* pointer.

The *shmem_free* routine returns no value.

The *shmem_realloc* routine returns a pointer to the allocated space (which may have moved); otherwise, it returns a null pointer.

The *shmem_align* routine returns an aligned pointer to the allocated space; otherwise, it returns a *NULL* pointer.

Notes

As of Specification 1.2 the use of *shmalloc*, *shmemalign*, *shfree*, and *shrealloc* has been deprecated. Although OpenSHMEM libraries are required to support the calls, program users are encouraged to use *shmem_malloc*, *shmem_align*, *shmem_free*, and *shmem_realloc* instead. The behavior and signature of the routines remains unchanged from the deprecated versions.

The total size of the symmetric heap is determined at job startup. One can adjust the size of the heap using the *SMA_SYMMETRIC_SIZE* environment variable (where available).

The *shmem_malloc*, *shmem_free*, and *shmem_realloc* routines differ from the private heap allocation routines in that all PEs in a program must call them (a barrier is used to ensure this).

Note to implementors

The symmetric heap allocation routines always return a pointer to corresponding symmetric objects across all PEs. The OpenSHMEM specification does not require that the virtual addresses are equal across all PEs. Nevertheless, the implementation must avoid costly address translation operations in the communication path, including order *N* (where *N* is the number of PEs) memory translation tables. In order to avoid address translations, the implementation may re-map the allocated block of memory based on agreed virtual address. Additionally, some operating systems provide an option to disable virtual address randomization, which enables predictable allocation of virtual memory addresses.

8.2.2 SHPALLOC

Allocates a block of memory from the symmetric heap.

SYNOPSIS

FORTRAN:

```
POINTER (addr, A(1))
INTEGER length, errcode, abort
CALL SHPALLOC(addr, length, errcode, abort)
```

DESCRIPTION

Arguments

OUT	*addr*	First word address of the allocated block.
IN	*length*	Number of words of memory requested. One word is 32 bits.
OUT	*errcode*	Error code is *0* if no error was detected; otherwise, it is a negative integer code for the type of error.
IN	*abort*	Abort code; nonzero requests abort on error; *0* requests an error code.

API description

SHPALLOC allocates a block of memory from the program's symmetric heap that is greater than or equal to the size requested. To maintain symmetric heap consistency, all PEs in an program must call *SHPALLOC* with the same value of length; if any PEs are missing, the program will hang.

By using the *Fortran POINTER* mechanism in the following manner, you can use array *A* to refer to the block allocated by *SHPALLOC*: *POINTER* (*addr*, *A*())

Return Values

Error Code	Condition
-1	Length is not an integer greater than *0*
-2	No more memory is available from the system (checked if the request cannot be satisfied from the available blocks on the symmetric heap).

Notes

The total size of the symmetric heap is determined at job startup. One may adjust the size of the heap using the *SMA_SYMMETRIC_SIZE* environment variable (if available).

Note to implementors

The symmetric heap allocation routines always return a pointer to corresponding symmetric objects across all PEs. The OpenSHMEM specification does not require that the virtual addresses are equal across all PEs. Nevertheless, the implementation must avoid costly address translation operations in the communication path, including order *N* (where *N* is the number of PEs) memory translation tables. In order to avoid address translations, the implementation may re-map the allocated block of memory based on agreed virtual address. Additionally, some operating systems provide an option to disable virtual address randomization, which enables predictable allocation of virtual memory addresses.

8.2.3 SHPCLMOVE

Extends a symmetric heap block or copies the contents of the block into a larger block.

SYNOPSIS

FORTRAN:

```
POINTER (addr, A(1))
INTEGER length, status, abort
CALL SHPCLMOVE (addr, length, status, abort)
```

DESCRIPTION

Arguments

INOUT	*addr*	On entry, first word address of the block to change; on exit, the new address of the block if it was moved.
IN	*length*	Requested new total length in words. One word is *32* bits.
OUT	*status*	Status is *0* if the block was extended in place, *1* if it was moved, and a negative integer for the type of error detected.
IN	*abort*	Abort code. Nonzero requests abort on error; *0* requests an error code.

API description

The *SHPCLMOVE* routine either extends a symmetric heap block if the block is followed by a large enough free block or copies the contents of the existing block to a larger block and returns a status code indicating that the block was moved. This routine also can reduce the size of a block if the new length is less than the old length. All PEs in a program must call *SHPCLMOVE* with the same value of *addr* to maintain symmetric heap consistency; if any PEs are missing, the program hangs.

Return Values

Error Code	Condition
-1	Length is not an integer greater than *0*
-2	No more memory is available from the system (checked if the request cannot be satisfied from the available blocks on the symmetric heap).
-3	Address is outside the bounds of the symmetric heap.
-4	Block is already free.
-5	Address is not at the beginning of a block.

Notes

None.

8.2.4 SHPDEALLOC

Returns a memory block to the symmetric heap.

SYNOPSIS

FORTRAN:

```
POINTER (addr, A(1))
INTEGER errcode, abort
CALL SHPDEALLC(addr, errcode, abort)
```

DESCRIPTION

Arguments

IN	*addr*	First word address of the block to deallocate.
OUT	*errcode*	Error code is 0 if no error was detected; otherwise, it is a negative integer code for the type of error.
IN	*abort*	Abort code. Nonzero requests abort on error; *0* requests an error code.

API description

SHPDEALLC returns a block of memory (allocated using *SHPALLOC*) to the list of available space in the symmetric heap. To maintain symmetric heap consistency, all PEs in a program must call *SHPDEALLC* with the same value of *addr*; if any PEs are missing, the program hangs.

Return Values

Error Code	Condition
-1	Length is not an integer greater than 0

-2	No more memory is available from the system (checked if the request cannot be satisfied from the available blocks on the symmetric heap).
-3	Address is outside the bounds of the symmetric heap.
-4	Block is already free.
-5	Address is not at the beginning of a block.

Notes

None.

8.3 Remote Memory Access Routines

The *Remote Memory Access* (RMA) routines described in this section are one-sided communication mechanisms of the OpenSHMEM API. While using these mechanisms, the user is required to provide parameters only on the calling side. A characteristic of one-sided communication is that it decouples communication from the synchronization. One-sided communication mechanisms transfer the data but do not synchronize the sender of the data with the receiver of the data.

OpenSHMEM RMA routines are all performed on the symmetric objects. The initiator PE of the call is designated as *source*, and the PE in which memory is accessed is designated as *dest*. In the case of the remote update routine, *Put*, the origin is the *source* PE and the destination PE is the *dest* PE. In the case of the remote read routine, *Get*, the origin is the *dest* PE and the destination is the *source* PE.

Where appropriate compiler support is available, OpenSHMEM provides type-generic one-sided communication interfaces via *C11* generic selection (*C11* §6.5.1.1[4]) for block, scalar, and block-strided put and get communication. Such type-generic routines are supported for the "standard RMA types" identified in Table 1.

TYPE	*TYPENAME*
float	float
double	double
long double	longdouble
char	char
short	short
int	int
long	long
long long	longlong

Table 1: Standard RMA Types and Names

8.3.1 SHMEM_PUT

The put routines provide a method for copying data from a contiguous local data object to a data object on a specified PE.

SYNOPSIS

C11:

```
void shmem_put(TYPE *dest, const TYPE *source, size_t nelems, int pe);
```

where *TYPE* is one of the standard RMA types specified by Table 1.

C/C++:

[4]Formally, the *C11* specification is ISO/IEC 9899:2011(E).

```
void shmem_<TYPENAME>_put(TYPE *dest, const TYPE *source, size_t nelems, int pe);
```

where *TYPE* is one of the standard RMA types and has a corresponding *TYPENAME* specified by Table 1.

```
void shmem_put<SIZE>(void *dest, const void *source, size_t nelems, int pe);
```

where *SIZE* is one of *8, 16, 32, 64, 128*.

```
void shmem_putmem(void *dest, const void *source, size_t nelems, int pe);
```

FORTRAN:

```
CALL SHMEM_CHARACTER_PUT(dest, source, nelems, pe)
CALL SHMEM_COMPLEX_PUT(dest, source, nelems, pe)
CALL SHMEM_DOUBLE_PUT(dest, source, nelems, pe)
CALL SHMEM_INTEGER_PUT(dest, source, nelems, pe)
CALL SHMEM_LOGICAL_PUT(dest, source, nelems, pe)
CALL SHMEM_PUT4(dest, source, nelems, pe)
CALL SHMEM_PUT8(dest, source, nelems, pe)
CALL SHMEM_PUT32(dest, source, nelems, pe)
CALL SHMEM_PUT64(dest, source, nelems, pe)
CALL SHMEM_PUT128(dest, source, nelems, pe)
CALL SHMEM_PUTMEM(dest, source, nelems, pe)
CALL SHMEM_REAL_PUT(dest, source, nelems, pe)
```

DESCRIPTION

Arguments

IN	*dest*	Data object to be updated on the remote PE. This data object must be remotely accessible.
OUT	*source*	Data object containing the data to be copied.
IN	*nelems*	Number of elements in the *dest* and *source* arrays. *nelems* must be of type *size_t* for *C*. If you are using *Fortran*, it must be a constant, variable, or array element of default integer type.
IN	*pe*	PE number of the remote PE. *pe* must be of type integer. If you are using *Fortran*, it must be a constant, variable, or array element of default integer type.

API description

The routines return after the data has been copied out of the *source* array on the local PE. The delivery of data words into the data object on the destination PE may occur in any order. Furthermore, two successive put routines may deliver data out of order unless a call to *shmem_fence* is introduced between the two calls.

The *dest* and *source* data objects must conform to certain typing constraints, which are as follows:

Routine	Data type of *dest* and *source*
shmem_putmem	*Fortran*: Any noncharacter type. *C*: Any data type. nelems is scaled in bytes.
shmem_put4, shmem_put32	Any noncharacter type that has a storage size equal to *32* bits.
shmem_put8	*C*: Any noncharacter type that has a storage size equal to *8* bits. *Fortran*: Any noncharacter type that has a storage size equal to *64* bits.
shmem_put64	Any noncharacter type that has a storage size equal to *64* bits.
shmem_put128	Any noncharacter type that has a storage size equal to *128* bits.
SHMEM_CHARACTER_PUT	Elements of type character. *nelems* is the number of characters to transfer. The actual character lengths of the *source* and *dest* variables are ignored.

SHMEM_COMPLEX_PUT	Elements of type complex of default size.
SHMEM_DOUBLE_PUT	Elements of type double precision.
SHMEM_INTEGER_PUT	Elements of type integer.
SHMEM_LOGICAL_PUT	Elements of type logical.
SHMEM_REAL_PUT	Elements of type real.

Return Values

None.

Notes

If you are using *Fortran*, data types must be of default size. For example, a real variable must be declared as *REAL*, *REAL*4*, or *REAL(KIND=KIND(1.0))*. The Fortran API routine *SHMEM_PUT* has been deprecated, and either *SHMEM_PUT8* or *SHMEM_PUT64* should be used in its place.

EXAMPLES

The following *shmem_put* example is for *C/C++* programs:

```
#include <stdio.h>
#include <shmem.h>

int main(void)
{
   long source[10] = { 1, 2, 3, 4, 5,
                       6, 7, 8, 9, 10 };
   static long dest[10];
   shmem_init();
   if (shmem_my_pe() == 0) {
      /* put 10 words into dest on PE 1 */
      shmem_put(dest, source, 10, 1);
   }
   shmem_barrier_all();  /* sync sender and receiver */
   printf("dest[0] on PE %d is %ld\n", shmem_my_pe(), dest[0]);
   return 0;
}
```

8.3.2 SHMEM_P

Copies one data item to a remote PE.

SYNOPSIS

C11:

```
void shmem_p(TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the standard RMA types specified by Table 1.

C/C++:

```
void shmem_<TYPENAME>_p(TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the standard RMA types and has a corresponding *TYPENAME* specified by Table 1.

DESCRIPTION

Arguments

IN	*addr*	The remotely accessible array element or scalar data object which will receive the data on the remote PE.

IN	*value*	The value to be transferred to *addr* on the remote PE.
IN	*pe*	The number of the remote PE.

API description

These routines provide a very low latency put capability for single elements of most basic types.

As with *shmem_put*, these routines start the remote transfer and may return before the data is delivered to the remote PE. Use *shmem_quiet* to force completion of all remote *Put* transfers.

Return Values

None.

Notes

None.

EXAMPLES

The following example uses *shmem_p* in a *C* program.

```
#include <stdio.h>
#include <math.h>
#include <shmem.h>
static const double e = 2.71828182;
static const double epsilon = 0.00000001;

int main(void)
{
   double *f;
   int me;

   shmem_init();
   me = shmem_my_pe();
   f = (double *) shmem_malloc(sizeof (*f));

   *f = 3.1415927;
   shmem_barrier_all();

   if (me == 0)
      shmem_p(f, e, 1);

   shmem_barrier_all();
   if (me == 1)
      printf("%s\n", (fabs (*f - e) < epsilon) ? "OK" : "FAIL");

   return 0;
}
```

8.3.3 SHMEM_IPUT

Copies strided data to a specified PE.

SYNOPSIS

C11:

```
void shmem_iput(TYPE *dest, const TYPE *source, ptrdiff_t dst, ptrdiff_t sst, size_t nelems,
    int pe);
```

where *TYPE* is one of the standard RMA types specified by Table 1.

C/C++:

```
void shmem_<TYPENAME>_iput(TYPE *dest, const TYPE *source, ptrdiff_t dst, ptrdiff_t sst,
    size_t nelems, int pe);
```

where *TYPE* is one of the standard RMA types and has a corresponding *TYPENAME* specified by Table 1.

```
void shmem_iput<SIZE>(void *dest, const void *source, ptrdiff_t dst, ptrdiff_t sst, size_t
    nelems, int pe);
```

where *SIZE* is one of *8, 16, 32, 64, 128*.

FORTRAN:

```
INTEGER dst, sst, nelems, pe
CALL SHMEM_COMPLEX_IPUT(dest, source, dst, sst, nelems, pe)
CALL SHMEM_DOUBLE_IPUT(dest, source, dst, sst, nelems, pe)
CALL SHMEM_INTEGER_IPUT(dest, source, dst, sst, nelems, pe)
CALL SHMEM_IPUT4(dest, source, dst, sst, nelems, pe)
CALL SHMEM_IPUT8(dest, source, dst, sst, nelems, pe)
CALL SHMEM_IPUT32(dest, source, dst, sst, nelems, pe)
CALL SHMEM_IPUT64(dest, source, dst, sst, nelems, pe)
CALL SHMEM_IPUT128(dest, source, dst, sst, nelems, pe)
CALL SHMEM_LOGICAL_IPUT(dest, source, dst, sst, nelems, pe)
CALL SHMEM_REAL_IPUT(dest, source, dst, sst, nelems, pe)
```

DESCRIPTION

Arguments

OUT	*dest*	Array to be updated on the remote PE. This data object must be remotely accessible.
IN	*source*	Array containing the data to be copied.
IN	*dst*	The stride between consecutive elements of the *dest* array. The stride is scaled by the element size of the *dest* array. A value of *1* indicates contiguous data. *dst* must be of type *ptrdiff_t*. If you are using *Fortran*, it must be a default integer value.
IN	*sst*	The stride between consecutive elements of the *source* array. The stride is scaled by the element size of the *source* array. A value of *1* indicates contiguous data. *sst* must be of type *ptrdiff_t*. If you are using *Fortran*, it must be a default integer value.
IN	*nelems*	Number of elements in the *dest* and *source* arrays. *nelems* must be of type *size_t* for *C*. If you are using *Fortran*, it must be a constant, variable, or array element of default integer type.
IN	*pe*	PE number of the remote PE. *pe* must be of type integer. If you are using *Fortran*, it must be a constant, variable, or array element of default integer type.

API description

The *iput* routines provide a method for copying strided data elements (specified by *sst*) of an array from a *source* array on the local PE to locations specified by stride *dst* on a *dest* array on specified remote PE. Both strides, *dst* and *sst*, must be greater than or equal to *1*. The routines return when the data has been copied out of the *source* array on the local PE but not necessarily before the data has been delivered to the remote data object.

The *dest* and *source* data objects must conform to typing constraints, which are as follows:

Routine	Data type of *dest* and *source*
shmem_iput4, shmem_iput32	Any noncharacter type that has a storage size equal to *32* bits.

shmem_iput8	*C*: Any noncharacter type that has a storage size equal to *8* bits. *Fortran*: Any noncharacter type that has a storage size equal to *64* bits.
shmem_iput64	Any noncharacter type that has a storage size equal to *64* bits.
shmem_iput128	Any noncharacter type that has a storage size equal to *128* bits.
SHMEM_COMPLEX_IPUT	Elements of type complex of default size.
SHMEM_DOUBLE_IPUT	Elements of type double precision.
SHMEM_INTEGER_IPUT	Elements of type integer.
SHMEM_LOGICAL_IPUT	Elements of type logical.
SHMEM_REAL_IPUT	Elements of type real.

Return Values

None.

Notes

If you are using *Fortran*, data types must be of default size. For example, a real variable must be declared as *REAL*, *REAL*4* or *REAL(KIND=KIND(1.0))*. See Section 3 for a definition of the term remotely accessible.

EXAMPLES

Consider the following *shmem_iput* example for *C/C++* programs.

```
#include <stdio.h>
#include <shmem.h>

int main(void)
{
   short source[10] = { 1, 2, 3, 4, 5,
                        6, 7, 8, 9, 10 };
   static short dest[10];
   shmem_init();
   if (shmem_my_pe() == 0) {
      /* put 5 words into dest on PE 1 */
      shmem_iput(dest, source, 1, 2, 5, 1);
   }
   shmem_barrier_all();   /* sync sender and receiver */
   if (shmem_my_pe() == 1) {
      printf("dest on PE %d is %d %d %d %d %d\n", shmem_my_pe(),
      (int)dest[0], (int)dest[1], (int)dest[2],
      (int)dest[3], (int)dest[4] );
   }
   shmem_barrier_all();   /* sync before exiting */
   return 0;
}
```

8.3.4 SHMEM_GET

Copies data from a specified PE.

SYNOPSIS

C11:

```
void shmem_get(TYPE *dest, const TYPE *source, size_t nelems, int pe);
```

where *TYPE* is one of the standard RMA types specified by Table 1.

C/C++:

```
void shmem_<TYPENAME>_get(TYPE *dest, const TYPE *source, size_t nelems, int pe);
```

where *TYPE* is one of the standard RMA types and has a corresponding *TYPENAME* specified by Table 1.

```
void shmem_get<SIZE>(void *dest, const void *source, size_t  nelems, int pe);
```

where *SIZE* is one of *8, 16, 32, 64, 128*.

```
void shmem_getmem(void *dest, const void *source, size_t nelems, int pe);
```

FORTRAN:

```
INTEGER nelems, pe
CALL SHMEM_CHARACTER_GET(dest, source, nelems, pe)
CALL SHMEM_COMPLEX_GET(dest, source, nelems, pe)
CALL SHMEM_DOUBLE_GET(dest, source, nelems, pe)
CALL SHMEM_GET4(dest, source, nelems, pe)
CALL SHMEM_GET8(dest, source, nelems, pe)
CALL SHMEM_GET32(dest, source, nelems, pe)
CALL SHMEM_GET128(dest, source, nelems, pe)
CALL SHMEM_GETMEM(dest, source, nelems, pe)
CALL SHMEM_INTEGER_GET(dest, source, nelems, pe)
CALL SHMEM_LOGICAL_GET(dest, source, nelems, pe)
CALL SHMEM_REAL_GET(dest, source, nelems, pe)
```

DESCRIPTION

Arguments

OUT	*dest*	Local data object to be updated.
IN	*source*	Data object on the PE identified by *pe* that contains the data to be copied. This data object must be remotely accessible.
IN	*nelems*	Number of elements in the *dest* and *source* arrays. *nelems* must be of type *size_t* for *C*. If you are using *Fortran*, it must be a constant, variable, or array element of default integer type.
IN	*pe*	PE number of the remote PE. *pe* must be of type integer. If you are using *Fortran*, it must be a constant, variable, or array element of default integer type.

API description

The get routines provide a method for copying a contiguous symmetric data object from a different PE to a contiguous data object on the local PE. The routines return after the data has been delivered to the *dest* array on the local PE.

The *dest* and *source* data objects must conform to typing constraints, which are as follows:

Routine	Data type of *dest* and *source*
shmem_getmem	*Fortran*: Any noncharacter type. *C*: Any data type. nelems is scaled in bytes.
shmem_get4, shmem_get32	Any noncharacter type that has a storage size equal to *32* bits.
shmem_get8	*C*: Any noncharacter type that has a storage size equal to *8* bits. *Fortran*: Any noncharacter type that has a storage size equal to *64* bits.
shmem_get64	Any noncharacter type that has a storage size equal to *64* bits.
shmem_get128	Any noncharacter type that has a storage size equal to *128* bits.
SHMEM_CHARACTER_GET	Elements of type character. *nelems* is the number of characters to transfer. The actual character lengths of the *source* and *dest* variables are ignored.

SHMEM_COMPLEX_GET	Elements of type complex of default size.
SHMEM_DOUBLE_GET	*Fortran*: Elements of type double precision.
SHMEM_INTEGER_GET	Elements of type integer.
SHMEM_LOGICAL_GET	Elements of type logical.
SHMEM_REAL_GET	Elements of type real.

Return Values

None.

Notes

See Section 3 for a definition of the term remotely accessible. If you are using *Fortran*, data types must be of default size. For example, a real variable must be declared as *REAL*, *REAL*4*, or *REAL(KIND=KIND(1.0))*.

EXAMPLES

Consider this example for *Fortran*.

```
PROGRAM REDUCTION
INCLUDE "shmem.fh"

REAL VALUES, SUM
COMMON /C/ VALUES
REAL WORK
CALL SHMEM_INIT()              ! ALLOW ANY NUMBER OF PES
VALUES = SHMEM_MY_PE()               ! INITIALIZE IT TO SOMETHING
CALL SHMEM_BARRIER_ALL
SUM = 0.0
DO I = 0, SHMEM_N_PES()-1
   CALL SHMEM_REAL_GET(WORK, VALUES, (SHMEM_N_PES()()-1), I)
   SUM = SUM + WORK
ENDDO
PRINT*,'PE ',SHMEM_MY_PE(),' COMPUTED SUM=',SUM
CALL SHMEM_BARRIER_ALL
END
```

8.3.5 SHMEM_G

Copies one data item from a remote PE

SYNOPSIS

C11:

```
TYPE shmem_g(const TYPE *addr, int pe);
```

where *TYPE* is one of the standard RMA types specified by Table 1.

C/C++:

```
TYPE shmem_<TYPENAME>_g(const TYPE *addr, int pe);
```

where *TYPE* is one of the standard RMA types and has a corresponding *TYPENAME* specified by Table 1.

DESCRIPTION

Arguments

IN	*addr*	The remotely accessible array element or scalar data object.
IN	*pe*	The number of the remote PE on which *addr* resides.

API description

These routines provide a very low latency get capability for single elements of most basic types.

Return Values

Returns a single element of type specified in the synopsis.

Notes

None.

EXAMPLES

The following *shmem_g* example is for *C/C++* programs:

```
#include <stdio.h>
#include <shmem.h>

long x = 10101;

int main(void)
{
   int me, npes;
   long y = -1;

   shmem_init();
   me = shmem_my_pe();
   npes = shmem_n_pes();

   if (me == 0)
      y = shmem_g(&x, npes-1);

   printf("%d: y = %ld\n", me, y);

   return 0;
}
```

8.3.6 SHMEM_IGET

Copies strided data from a specified PE.

SYNOPSIS

C11:

```
void shmem_iget(TYPE *dest, const TYPE *source, ptrdiff_t dst, ptrdiff_t sst, size_t nelems,
    int pe);
```

where *TYPE* is one of the standard RMA types specified by Table 1.

C/C++:

```
void shmem_<TYPENAME>_iget(TYPE *dest, const TYPE *source, ptrdiff_t dst, ptrdiff_t sst,
    size_t nelems, int pe);
```

where *TYPE* is one of the standard RMA types and has a corresponding *TYPENAME* specified by Table 1.

```
void shmem_iget<SIZE>(void *dest, const void *source, ptrdiff_t dst, ptrdiff_t sst, size_t
    nelems, int pe);
```

where *SIZE* is one of *8, 16, 32, 64, 128*.

FORTRAN:

```
INTEGER dst, sst, nelems, pe
CALL SHMEM_COMPLEX_IGET(dest, source, dst, sst, nelems, pe)
CALL SHMEM_DOUBLE_IGET(dest, source, dst, sst, nelems, pe)
CALL SHMEM_IGET4(dest, source, dst, sst, nelems, pe)
CALL SHMEM_IGET8(dest, source, dst, sst, nelems, pe)
CALL SHMEM_IGET32(dest, source, dst, sst, nelems, pe)
CALL SHMEM_IGET64(dest, source, dst, sst, nelems, pe)
CALL SHMEM_IGET128(dest, source, dst, sst, nelems, pe)
CALL SHMEM_INTEGER_IGET(dest, source, dst, sst, nelems, pe)
CALL SHMEM_LOGICAL_IGET(dest, source, dst, sst, nelems, pe)
CALL SHMEM_REAL_IGET(dest, source, dst, sst, nelems, pe)
```

DESCRIPTION

Arguments

OUT	*dest*	Array to be updated on the local PE.
IN	*source*	Array containing the data to be copied on the remote PE.
IN	*dst*	The stride between consecutive elements of the *dest* array. The stride is scaled by the element size of the *dest* array. A value of *1* indicates contiguous data. *dst* must be of type *ptrdiff_t*. If you are calling from *Fortran*, it must be a default integer value.
IN	*sst*	The stride between consecutive elements of the *source* array. The stride is scaled by the element size of the *source* array. A value of *1* indicates contiguous data. *sst* must be of type *ptrdiff_t*. If you are calling from *Fortran*, it must be a default integer value.
IN	*nelems*	Number of elements in the *dest* and *source* arrays. *nelems* must be of type *size_t* for *C*. If you are using *Fortran*, it must be a constant, variable, or array element of default integer type.
IN	*pe*	PE number of the remote PE. *pe* must be of type integer. If you are using *Fortran*, it must be a constant, variable, or array element of default integer type.

API description

The *iget* routines provide a method for copying strided data elements from a symmetric array from a specified remote PE to strided locations on a local array. The routines return when the data has been copied into the local *dest* array.

The *dest* and *source* data objects must conform to typing constraints, which are as follows:

Routine	Data type of *dest* and *source*
shmem_iget4, shmem_iget32	Any noncharacter type that has a storage size equal to *32* bits.
shmem_iget8	*C*: Any noncharacter type that has a storage size equal to *8* bits. *Fortran*: Any noncharacter type that has a storage size equal to *64* bits.
shmem_iget64	Any noncharacter type that has a storage size equal to *64* bits.
shmem_iget128	Any noncharacter type that has a storage size equal to *128* bits.
SHMEM_COMPLEX_IGET	Elements of type complex of default size.
SHMEM_DOUBLE_IGET	*Fortran*: Elements of type double precision.
SHMEM_INTEGER_IGET	Elements of type integer.
SHMEM_LOGICAL_IGET	Elements of type logical.
SHMEM_REAL_IGET	Elements of type real.

Return Values

None.

Notes

If you are using *Fortran*, data types must be of default size. For example, a real variable must be declared as *REAL*, *REAL*4*, or *REAL(KIND=KIND(1.0))*.

EXAMPLES

The following example uses *shmem_logical_iget* in a *Fortran* program.

```
PROGRAM STRIDELOGICAL
INCLUDE "shmem.fh"

LOGICAL SOURCE(10), DEST(5)
SAVE SOURCE   ! SAVE MAKES IT REMOTELY ACCESSIBLE
DATA SOURCE /.T.,.F.,.T.,.F.,.T.,.F.,.T.,.F.,.T.,.F./
DATA DEST / 5*.F. /
CALL SHMEM_INIT()
IF (SHMEM_MY_PE() .EQ. 0) THEN
   CALL SHMEM_LOGICAL_IGET(DEST, SOURCE, 1, 2, 5, 1)
   PRINT*,'DEST AFTER SHMEM_LOGICAL_IGET:',DEST
ENDIF
CALL SHMEM_BARRIER_ALL
```

8.4 Non-blocking Remote Memory Access Routines

8.4.1 SHMEM_PUT_NBI

The nonblocking put routines provide a method for copying data from a contiguous local data object to a data object on a specified PE.

SYNOPSIS

C11:

```
void shmem_put_nbi(TYPE *dest, const TYPE *source, size_t nelems, int pe);
```

where *TYPE* is one of the standard RMA types specified by Table 1.

C/C++:

```
void shmem_<TYPENAME>_put_nbi(TYPE *dest, const TYPE *source, size_t nelems, int pe);
```

where *TYPE* is one of the standard RMA types and has a corresponding *TYPENAME* specified by Table 1.

```
void shmem_put<SIZE>_nbi(void *dest, const void *source, size_t nelems, int pe);
```

where *SIZE* is one of *8, 16, 32, 64, 128*.

```
void shmem_putmem_nbi(void *dest, const void *source, size_t nelems, int pe);
```

FORTRAN:

```
CALL SHMEM_CHARACTER_PUT_NBI(dest, source, nelems, pe)
CALL SHMEM_COMPLEX_PUT_NBI(dest, source, nelems, pe)
CALL SHMEM_DOUBLE_PUT_NBI(dest, source, nelems, pe)
CALL SHMEM_INTEGER_PUT_NBI(dest, source, nelems, pe)
CALL SHMEM_LOGICAL_PUT_NBI(dest, source, nelems, pe)
CALL SHMEM_PUT4_NBI(dest, source, nelems, pe)
CALL SHMEM_PUT8_NBI(dest, source, nelems, pe)
CALL SHMEM_PUT32_NBI(dest, source, nelems, pe)
CALL SHMEM_PUT64_NBI(dest, source, nelems, pe)
```

```
CALL SHMEM_PUT128_NBI(dest, source, nelems, pe)
CALL SHMEM_PUTMEM_NBI(dest, source, nelems, pe)
CALL SHMEM_REAL_PUT_NBI(dest, source, nelems, pe)
```

DESCRIPTION

Arguments

OUT	*dest*	Data object to be updated on the remote PE. This data object must be remotely accessible.
IN	*source*	Data object containing the data to be copied.
IN	*nelems*	Number of elements in the *dest* and *source* arrays. *nelems* must be of type *size_t* for *C*. If you are using *Fortran*, it must be a constant, variable, or array element of default integer type.
IN	*pe*	PE number of the remote PE. *pe* must be of type integer. If you are using *Fortran*, it must be a constant, variable, or array element of default integer type.

API description

The routines return after posting the operation. The operation is considered complete after a subsequent call to *shmem_quiet*. At the completion of *shmem_quiet*, the data has been copied into the *dest* array on the destination PE. The delivery of data words into the data object on the destination PE may occur in any order. Furthermore, two successive put routines may deliver data out of order unless a call to *shmem_fence* is introduced between the two calls.

The *dest* and *source* data objects must conform to certain typing constraints, which are as follows:

Routine	Data type of *dest* and *source*
shmem_putmem_nbi	*Fortran*: Any noncharacter type. *C*: Any data type. nelems is scaled in bytes.
shmem_put4_nbi, shmem_put32_nbi	Any noncharacter type that has a storage size equal to *32* bits.
shmem_put8_nbi	*C*: Any noncharacter type that has a storage size equal to *8* bits. *Fortran*: Any noncharacter type that has a storage size equal to *64* bits.
shmem_put64_nbi	Any noncharacter type that has a storage size equal to *64* bits.
shmem_put128_nbi	Any noncharacter type that has a storage size equal to *128* bits.
SHMEM_CHARACTER_PUT_NBI	Elements of type character. *nelems* is the number of characters to transfer. The actual character lengths of the *source* and *dest* variables are ignored.
SHMEM_COMPLEX_PUT_NBI	Elements of type complex of default size.
SHMEM_DOUBLE_PUT_NBI	Elements of type double precision.
SHMEM_INTEGER_PUT_NBI	Elements of type integer.
SHMEM_LOGICAL_PUT_NBI	Elements of type logical.
SHMEM_REAL_PUT_NBI	Elements of type real.

Return Values

None.

Notes

None.

8.4.2 SHMEM_GET_NBI

The nonblocking get routines provide a method for copying data from a contiguous remote data object on the specified PE to the local data object.

SYNOPSIS

C11:

```
void shmem_get_nbi(TYPE *dest, const TYPE *source, size_t nelems, int pe);
```

where *TYPE* is one of the standard RMA types specified by Table 1.

C/C++:

```
void shmem_<TYPENAME>_get_nbi(TYPE *dest, const TYPE *source, size_t nelems, int pe);
```

where *TYPE* is one of the standard RMA types and has a corresponding *TYPENAME* specified by Table 1.

```
void shmem_get<SIZE>_nbi(void *dest, const void *source, size_t  nelems, int pe);
```

where *SIZE* is one of *8, 16, 32, 64, 128*.

```
void shmem_getmem_nbi(void *dest, const void *source, size_t nelems, int pe);
```

FORTRAN:

```
INTEGER nelems, pe
CALL SHMEM_CHARACTER_GET_NBI(dest, source, nelems, pe)
CALL SHMEM_COMPLEX_GET_NBI(dest, source, nelems, pe)
CALL SHMEM_DOUBLE_GET_NBI(dest, source, nelems, pe)
CALL SHMEM_GET4_NBI(dest, source, nelems, pe)
CALL SHMEM_GET8_NBI(dest, source, nelems, pe)
CALL SHMEM_GET32_NBI(dest, source, nelems, pe)
CALL SHMEM_GET128_NBI(dest, source, nelems, pe)
CALL SHMEM_GETMEM_NBI(dest, source, nelems, pe)
CALL SHMEM_INTEGER_GET_NBI(dest, source, nelems, pe)
CALL SHMEM_LOGICAL_GET_NBI(dest, source, nelems, pe)
CALL SHMEM_REAL_GET_NBI(dest, source, nelems, pe)
```

DESCRIPTION

Arguments

OUT	*dest*	Local data object to be updated.
IN	*source*	Data object on the PE identified by *pe* that contains the data to be copied. This data object must be remotely accessible.
IN	*nelems*	Number of elements in the *dest* and *source* arrays. *nelems* must be of type *size_t* for *C*. If you are using *Fortran*, it must be a constant, variable, or array element of default integer type.
IN	*pe*	PE number of the remote PE. *pe* must be of type integer. If you are using *Fortran*, it must be a constant, variable, or array element of default integer type.

API description

The get routines provide a method for copying a contiguous symmetric data object from a different PE to a contiguous data object on the local PE. The routines return after posting the operation. The operation is considered complete after a subsequent call to *shmem_quiet*. At the completion of *shmem_quiet*, the data has been delivered to the *dest* array on the local PE.

The *dest* and *source* data objects must conform to typing constraints, which are as follows:

Routine	Data type of *dest* and *source*
shmem_getmem_nbi	*Fortran*: Any noncharacter type. *C*: Any data type. nelems is scaled in bytes.
shmem_get4_nbi, shmem_get32_nbi	Any noncharacter type that has a storage size equal to *32* bits.
shmem_get8_nbi	*C*: Any noncharacter type that has a storage size equal to *8* bits. *Fortran*: Any noncharacter type that has a storage size equal to *64* bits.
shmem_get64_nbi	Any noncharacter type that has a storage size equal to *64* bits.
shmem_get128_nbi	Any noncharacter type that has a storage size equal to *128* bits.
SHMEM_CHARACTER_GET_NBI	Elements of type character. *nelems* is the number of characters to transfer. The actual character lengths of the *source* and *dest* variables are ignored.
SHMEM_COMPLEX_GET_NBI	Elements of type complex of default size.
SHMEM_DOUBLE_GET_NBI	*Fortran*: Elements of type double precision.
SHMEM_INTEGER_GET_NBI	Elements of type integer.
SHMEM_LOGICAL_GET_NBI	Elements of type logical.
SHMEM_REAL_GET_NBI	Elements of type real.

Return Values

None.

Notes

See Section 3 for a definition of the term remotely accessible. If you are using *Fortran*, data types must be of default size. For example, a real variable must be declared as *REAL*, *REAL*4*, or *REAL(KIND=KIND(1.0))*.

8.5 Atomic Memory Operations

An *Atomic Memory Operation* (AMO) is a one-sided communication mechanism that combines memory update operations with atomicity guarantees described in Section 4.2. Similar to the RMA routines, described in Section 8.3, the AMOs are performed only on symmetric objects. OpenSHMEM defines the two types of AMO routines:

- The *fetching* routines return the original value of, and optionally update, the remote data object in a single atomic operation. The routines return after the data has been fetched and delivered to the local PE.

  The *fetching* operations include: *SHMEM_FETCH*, *SHMEM_CSWAP*, *SHMEM_SWAP*, *SHMEM_FINC*, and *SHMEM_FADD*.

- The *non-fetching* atomic routines update the remote memory in a single atomic operation. A *non-fetching* atomic routine starts the atomic operation and may return before the operation execution on the remote PE. To force completion for these *non-fetching* atomic routines, *shmem_quiet*, *shmem_barrier*, or *shmem_barrier_all* can be used by an OpenSHMEM program.

  The *non-fetching* operations include: *SHMEM_SET*, *SHMEM_INC* and *SHMEM_ADD*.

Where appropriate compiler support is available, OpenSHMEM provides type-generic atomic memory operation interfaces via *C11* generic selection. The type-generic AMO routines each support the “standard AMO types” listed in Table 2, except for *shmem_fetch*, *shmem_set*, and *shmem_swap*, which supports the “extended AMO types” listed in Table 3.

TYPE	*TYPENAME*
int	int
long	long
long long	longlong

Table 2: Standard AMO Types and Names

TYPE	*TYPENAME*
float	float
double	double
int	int
long	long
long long	longlong

Table 3: Extended AMO Types and Names

8.5.1 SHMEM_ADD

Performs an atomic add operation on a remote symmetric data object.

SYNOPSIS

C11:

```
void shmem_add(TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the standard AMO types specified by Table 2.

C/C++:

```
void shmem_<TYPENAME>_add(TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the standard AMO types and has a corresponding *TYPENAME* specified by Table 2.

FORTRAN:

```
INTEGER pe
INTEGER*4  value_i4
CALL SHMEM_INT4_ADD(dest, value_i4, pe)
INTEGER*8 value_i8
CALL SHMEM_INT8_ADD(dest, value_i8, pe)
```

DESCRIPTION

Arguments

OUT	*dest*	The remotely accessible integer data object to be updated on the remote PE. If you are using *C/C++*, the type of *dest* should match that implied in the SYNOPSIS section.
IN	*value*	The value to be atomically added to *dest*. If you are using *C/C++*, the type of *value* should match that implied in the SYNOPSIS section. If you are using *Fortran*, it must be of type integer with an element size of *dest*.
IN	*pe*	An integer that indicates the PE number upon which *dest* is to be updated. If you are using *Fortran*, it must be a default integer value.

API description

The *shmem_add* routine performs an atomic add operation. It adds *value* to *dest* on PE *pe* and atomically updates the *dest* without returning the value.

If you are using *Fortran*, *dest* must be of the following type:

Routine	Data type of *dest*
SHMEM_INT4_ADD	*4*-byte integer
SHMEM_INT8_ADD	*8*-byte integer

Return Values

None.

Notes

The term remotely accessible is defined in Section 3.

EXAMPLES

```
#include <stdio.h>
#include <shmem.h>

int main(void)
{
   int me, old;
   static int dst;

   shmem_init();
   me = shmem_my_pe();

   old = -1;
   dst = 22;
   shmem_barrier_all();

   if (me == 1){
      old = shmem_add(&dst, 44, 0);
   }
   shmem_barrier_all();
   printf("%d: old = %d, dst = %d\n", me, old, dst);
   return 0;
}
```

8.5.2 SHMEM_CSWAP

Performs an atomic conditional swap on a remote data object.

SYNOPSIS

C11:

```
TYPE shmem_cswap(TYPE *dest, TYPE cond, TYPE value, int pe);
```

where *TYPE* is one of the standard AMO types specified by Table 2.

C/C++:

```
TYPE shmem_<TYPENAME>_cswap(TYPE *dest, TYPE cond, TYPE value, int pe);
```

where *TYPE* is one of the standard AMO types and has a corresponding *TYPENAME* specified by Table 2.

FORTRAN:

```
INTEGER pe
INTEGER*4 SHMEM_INT4_CSWAP,  cond_i4, value_i4, ires_i4
ires_i4 = SHMEM_INT4_CSWAP(dest, cond_i4, value_i4, pe)
INTEGER*8 SHMEM_INT8_CSWAP,  cond_i8, value_i8, ires_i8
ires_i8 = SHMEM_INT8_CSWAP(dest, cond_i8, value_i8, pe)
```

DESCRIPTION

Arguments

OUT	*dest*	The remotely accessible integer data object to be updated on the remote PE.
IN	*cond*	*cond* is compared to the remote *dest* value. If *cond* and the remote *dest* are equal, then *value* is swapped into the remote *dest*. Otherwise, the remote *dest* is unchanged. In either case, the old value of the remote *dest* is returned as the routine return value. *cond* must be of the same data type as *dest*.
IN	*value*	The value to be atomically written to the remote PE. *value* must be the same data type as *dest*.
IN	*pe*	An integer that indicates the PE number upon which *dest* is to be updated. If you are using *Fortran*, it must be a default integer value.

API description

The conditional swap routines conditionally update a *dest* data object on the specified PE and return the prior contents of the data object in one atomic operation.
The *dest* and *value* data objects must conform to certain typing constraints, which are as follows:

Routine	Data type of *dest* and *value*
SHMEM_INT4_CSWAP	*4*-byte integer.
SHMEM_INT8_CSWAP	*8*-byte integer.

Return Values

The contents that had been in the *dest* data object on the remote PE prior to the conditional swap. Data type is the same as the *dest* data type.

Notes

None.

EXAMPLES

The following call ensures that the first PE to execute the conditional swap will successfully write its PE number to *race_winner* on PE *0*.

```c
#include <stdio.h>
#include <shmem.h>

int main(void)
{
   static int  race_winner = -1;
   int oldval;
   shmem_init();
   oldval = shmem_cswap(&race_winner, -1, shmem_my_pe(), 0);
```

```
   if(oldval == -1) printf("pe %d was first\n",shmem_my_pe());
   return 1;
}
```

8.5.3 SHMEM_SWAP

Performs an atomic swap to a remote data object.

SYNOPSIS

C11:

```
TYPE shmem_swap(TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the extended AMO types specified by Table 3.

C/C++:

```
TYPE shmem_<TYPENAME>_swap(TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the extended AMO types and has a corresponding *TYPENAME* specified by Table 3.

FORTRAN:

```
INTEGER SHMEM_SWAP, value, pe
ires = SHMEM_SWAP(dest, value, pe)
INTEGER*4 SHMEM_INT4_SWAP, value_i4, ires_i4
ires_i4 = SHMEM_INT4_SWAP(dest, value_i4, pe)
INTEGER*8 SHMEM_INT8_SWAP, value_i8, ires_i8
ires_i8 = SHMEM_INT8_SWAP(dest, value_i8, pe)
REAL*4 SHMEM_REAL4_SWAP, value_r4, res_r4
res_r4 = SHMEM_REAL4_SWAP(dest, value_r4, pe)
REAL*8 SHMEM_REAL8_SWAP, value_r8, res_r8
res_r8 = SHMEM_REAL8_SWAP(dest, value_r8, pe)
```

DESCRIPTION

Arguments

OUT	*dest*	The remotely accessible integer data object to be updated on the remote PE. If you are using *C/C++*, the type of *dest* should match that implied in the SYNOPSIS section.
IN	*value*	The value to be atomically written to the remote PE. *value* is the same type as *dest*.
IN	*pe*	An integer that indicates the PE number on which *dest* is to be updated. If you are using *Fortran*, it must be a default integer value.

API description

shmem_swap performs an atomic swap operation. It writes *value* into *dest* on PE and returns the previous contents of *dest* as an atomic operation.

If you are using *Fortran*, *dest* must be of the following type:

Routine	Data type of *dest* and *source*
SHMEM_SWAP	Integer of default kind
SHMEM_INT4_SWAP	*4*-byte integer
SHMEM_INT8_SWAP	*8*-byte integer
SHMEM_REAL4_SWAP	*4*-byte real

SHMEM_REAL8_SWAP	*8*-byte real

Return Values

The content that had been at the *dest* address on the remote PE prior to the swap is returned.

Notes

None.

EXAMPLES

The example below swap values between odd numbered PEs and their right (modulo) neighbor and outputs the result of swap.

```
#include <stdio.h>
#include <shmem.h>

int main(void)
{
   long *dest;
   int me, npes;
   long swapped_val, new_val;

   shmem_init();
   me = shmem_my_pe();
   npes = shmem_n_pes();
   dest = (long *) shmem_malloc(sizeof (*dest));
   *dest = me;
   shmem_barrier_all();
   new_val = me;
   if (me & 1){
      swapped_val = shmem_swap(dest, new_val, (me + 1) % npes);
      printf("%d: dest = %ld, swapped = %ld\n", me, *dest, swapped_val);
   }
   shmem_free(dest);
   return 0;
}
```

8.5.4 SHMEM_FINC

Performs an atomic fetch-and-increment operation on a remote data object.

SYNOPSIS

C11:

```
TYPE shmem_finc(TYPE *dest, int pe);
```

where *TYPE* is one of the standard AMO types specified by Table 2.

C/C++:

```
TYPE shmem_<TYPENAME>_finc(TYPE *dest, int pe);
```

where *TYPE* is one of the standard AMO types and has a corresponding *TYPENAME* specified by Table 2.

FORTRAN:

```
INTEGER pe
INTEGER*4 SHMEM_INT4_FINC, ires_i4
ires_i4 = SHMEM_INT4_FINC(dest, pe)
INTEGER*8 SHMEM_INT8_FINC, ires_i8
ires_i8 = SHMEM_INT8_FINC(dest, pe)
```

DESCRIPTION

Arguments

IN	*dest*	The remotely accessible integer data object to be updated on the remote PE. The type of *dest* should match that implied in the SYNOPSIS section.
IN	*pe*	An integer that indicates the PE number on which *dest* is to be updated. If you are using *Fortran*, it must be a default integer value.

API description

These routines perform a fetch-and-increment operation. The *dest* on PE *pe* is increased by one and the routine returns the previous contents of *dest* as an atomic operation.

If you are using *Fortran*, *dest* must be of the following type:

Routine	Data type of *dest* and *source*
SHMEM_INT4_FINC	*4*-byte integer
SHMEM_INT8_FINC	*8*-byte integer

Return Values

The contents that had been at the *dest* address on the remote PE prior to the increment. The data type of the return value is the same as the *dest*.

Notes

None.

EXAMPLES

The following *shmem_finc* example is for *C/C++* programs:

```
#include <stdio.h>
#include <shmem.h>

int dst;

int main(void)
{
   int me;
   int old;

   shmem_init();
   me = shmem_my_pe();

   old = -1;
   dst = 22;
   shmem_barrier_all();

   if (me == 0)
      old = shmem_finc(&dst, 1);

   shmem_barrier_all();
```

```
    printf("%d: old = %d, dst = %d\n", me, old, dst);
    return 0;
}
```

8.5.5 SHMEM_INC

Performs an atomic increment operation on a remote data object.

SYNOPSIS

C11:

```
void shmem_inc(TYPE *dest, int pe);
```

where *TYPE* is one of the standard AMO types specified by Table 2.

C/C++:

```
void shmem_<TYPENAME>_inc(TYPE *dest, int pe);
```

where *TYPE* is one of the standard AMO types and has a corresponding *TYPENAME* specified by Table 2.

FORTRAN:

```
INTEGER pe
CALL SHMEM_INT4_INC(dest, pe)
CALL SHMEM_INT8_INC(dest, pe)
```

DESCRIPTION

Arguments

IN	*dest*	The remotely accessible integer data object to be updated on the remote PE. The type of *dest* should match that implied in the SYNOPSIS section.
IN	*pe*	An integer that indicates the PE number on which *dest* is to be updated. If you are using *Fortran*, it must be a default integer value.

API description

These routines perform an atomic increment operation on the *dest* data object on PE.

If you are using *Fortran*, *dest* must be of the following type:

Routine	Data type of *dest* and *source*
SHMEM_INT4_INC	*4*-byte integer
SHMEM_INT8_INC	*8*-byte integer

Return Values

None.

Notes

The term remotely accessible is defined in Section 3.

EXAMPLES

The following *shmem_inc* example is for *C/C++* programs:

```
#include <stdio.h>
#include <shmem.h>

int dst;

int main(void)
{
   int me;

   shmem_init();
   me = shmem_my_pe();

   dst = 74;
   shmem_barrier_all();

   if (me == 0)
      shmem_inc(&dst, 1);
   shmem_barrier_all();

   printf("%d: dst = %d\n", me, dst);
   return 0;
}
```

8.5.6 SHMEM_FADD

Performs an atomic fetch-and-add operation on a remote data object.

SYNOPSIS

C11:

```
TYPE shmem_fadd(TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the standard AMO types specified by Table 2.

C/C++:

```
TYPE shmem_<TYPENAME>_fadd(TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the standard AMO types and has a corresponding *TYPENAME* specified by Table 2.

FORTRAN:

```
INTEGER pe
INTEGER*4 SHMEM_INT4_FADD, ires_i4, value_i4
ires_i4 = SHMEM_INT4_FADD(dest, value_i4, pe)
INTEGER*8 SHMEM_INT8_FADD, ires_i8, value_i8
ires_i8 = SHMEM_INT8_FADD(dest, value_i8, pe)
```

DESCRIPTION

Arguments

OUT	*dest*	The remotely accessible integer data object to be updated on the remote PE. The type of *dest* should match that implied in the SYNOPSIS section.
IN	*value*	The value to be atomically added to *dest*. The type of *value* should match that implied in the SYNOPSIS section.
IN	*pe*	An integer that indicates the PE number on which *dest* is to be updated. If you are using *Fortran*, it must be a default integer value.

API description

shmem_fadd routines perform an atomic fetch-and-add operation. An atomic fetch-and-add operation fetches the old *dest* and adds *value* to *dest* without the possibility of another atomic operation on the *dest* between the time of the fetch and the update. These routines add *value* to *dest* on *pe* and return the previous contents of *dest* as an atomic operation.

If you are using *Fortran*, *dest* must be of the following type:

Routine	Data type of *dest* and *source*
SHMEM_INT4_FADD	*4*-byte integer
SHMEM_INT8_FADD	*8*-byte integer

Return Values

The contents that had been at the *dest* address on the remote PE prior to the atomic addition operation. The data type of the return value is the same as the *dest*.

Notes

None.

EXAMPLES

The following *shmem_fadd* example is for *C/C++* programs:

```
#include <stdio.h>
#include <shmem.h>

int main(void)
{
   int me, old;
   static int dst;

   shmem_init();
   me = shmem_my_pe();

   old = -1;
   dst = 22;
   shmem_barrier_all();

   if (me == 1){
      old = shmem_fadd(&dst, 44, 0);
   }
   shmem_barrier_all();
   printf("%d: old = %d, dst = %d\n", me, old, dst);
   return 0;
}
```

8.5.7 SHMEM_FETCH

Atomically fetches the value of a remote data object.

SYNOPSIS

C11:

```
TYPE shmem_fetch(const TYPE *dest, int pe);
```

where *TYPE* is one of the extended AMO types specified by Table 3.

C/C++:

```
TYPE shmem_<TYPENAME>_fetch(const TYPE *dest, int pe);
```

where *TYPE* is one of the extended AMO types and has a corresponding *TYPENAME* specified by Table 3.

FORTRAN:

```
INTEGER pe
INTEGER*4 SHMEM_INT4_FETCH, ires_i4
ires_i4 = SHMEM_INT4_FETCH(dest, pe)
INTEGER*8 SHMEM_INT8_FETCH, ires_i8
ires_i8 = SHMEM_INT8_FETCH(dest, pe)
REAL*4 SHMEM_REAL4_FETCH, res_r4
res_r4 = SHMEM_REAL4_FETCH(dest, pe)
REAL*8 SHMEM_REAL8_FETCH, res_r8
res_r8 = SHMEM_REAL8_FETCH(dest, pe)
```

DESCRIPTION

Arguments

IN	*dest*	The remotely accessible data object to be fetched from the remote PE.
IN	*pe*	An integer that indicates the PE number from which *dest* is to be fetched.

API description

shmem_fetch performs an atomic fetch operation. It returns the contents of the *dest* as an atomic operation.

Return Values

The contents at the *dest* address on the remote PE. The data type of the return value is the same as the the type of the remote data object.

Notes

None.

8.5.8 SHMEM_SET

Atomically sets the value of a remote data object.

SYNOPSIS

C11:

```
void shmem_set(TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the extended AMO types specified by Table 3.

C/C++:

```
void shmem_<TYPENAME>_set(TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the extended AMO types and has a corresponding *TYPENAME* specified by Table 3.

FORTRAN:

```
INTEGER pe
INTEGER*4 SHMEM_INT4_SET, value_i4
CALL SHMEM_INT4_SET(dest, value_i4, pe)
INTEGER*8 SHMEM_INT8_SET, value_i8
CALL SHMEM_INT8_SET(dest, value_i8, pe)
REAL*4 SHMEM_REAL4_SET, value_r4
CALL SHMEM_REAL4_SET(dest, value_r4, pe)
REAL*8 SHMEM_REAL8_SET, value_r8
CALL SHMEM_REAL8_SET(dest, value_r8, pe)
```

DESCRIPTION

Arguments

IN	*dest*	The remotely accessible data object to be set on the remote PE.
IN	*value*	The value to be atomically written to the remote PE.
IN	*pe*	An integer that indicates the PE number on which *dest* is to be updated.

API description

shmem_set performs an atomic set operation. It writes the *value* into *dest* on *pe* as an atomic operation.

Return Values

None.

Notes

None.

8.6 Collective Routines

Collective routines are defined as communication or synchronization operations on a group of PEs called an *Active set*. The collective routines require all PEs in the *Active set* to simultaneously call the routine. A PE that is not part of the *Active set* calling the collective routines results in an undefined behavior. All collective routines have an *Active set* as an input parameter except *SHMEM_BARRIER_ALL*. The *SHMEM_BARRIER_ALL* is called by all PEs of the OpenSHMEM program.

The *Active set* is defined by the arguments *PE_start*, *logPE_stride*, and *PE_size*. *PE_start* is the starting PE number, a log (base 2) of *logPE_stride* is the stride between PEs, and *PE_size* is the number of PEs participating in the *Active set*. All PEs participating in the collective routines provide the same values for these arguments.

Another argument important to collective routines is *pSync*, which is a symmetric work array. All PEs participating in a collective must pass the same *pSync* array. On completion of a collective call, the *pSync* is restored to its original contents. The user is permitted to reuse a *pSync* array if all previous collective routines using the *pSync* array have been completed by all participating PEs. One can use a synchronization collective routine such as *SHMEM_BARRIER* to ensure completion of previous collective routines. The *shmem_barrier* routine allows the same *pSync* array to be used on consecutive calls as long as the PE *Active set* does not change.

All collective routines defined in the specification are blocking. The collective routines return on completion. The collective routines defined in the OpenSHMEM specification are:

SHMEM_BROADCAST

SHMEM_BARRIER

SHMEM_BARRIER_ALL

SHMEM_COLLECT

SHMEM_FCOLLECT

Reduction Operations

SHMEM_ALLTOALL

SHMEM_ALLTOALLS

8.6.1 SHMEM_BARRIER_ALL

Registers the arrival of a PE at a barrier and suspends PE execution until all other PEs arrive at the barrier and all local and remote memory updates are completed.

SYNOPSIS

C/C++:
```
void shmem_barrier_all(void);
```
FORTRAN:
```
CALL SHMEM_BARRIER_ALL
```

DESCRIPTION

Arguments

None.

API description

The *shmem_barrier_all* routine registers the arrival of a PE at a barrier. Barriers are a fast mechanism for synchronizing all PEs at once. This routine causes a PE to suspend execution until all PEs have called *shmem_barrier_all*. This routine must be used with PEs started by *shmem_init*.

Prior to synchronizing with other PEs, *shmem_barrier_all* ensures completion of all previously issued memory stores and remote memory updates issued via OpenSHMEM AMOs and RMA routine calls such as *shmem_int_add*, *shmem_put32*, *shmem_put_nbi*, and *shmem_get_nbi*.

Return Values

None.

Notes

None.

EXAMPLES

The following *shmem_barrier_all* example is for *C/C++* programs:

```c
#include <stdio.h>
#include <shmem.h>

int x=1010;

int main(void)
{
   int me, npes;

   shmem_init();
   me = shmem_my_pe();
   npes = shmem_n_pes();

   /*put to next  PE in a circular fashion*/
   shmem_int_p(&x, 4, (me+1)%npes);
   /*synchronize all PEs*/
   shmem_barrier_all();

   printf("%d: x = %d\n", me, x);
   return 0;
}
```

8.6.2 SHMEM_BARRIER

Performs all operations described in the *shmem_barrier_all* interface but with respect to a subset of PEs defined by the *Active set*.

SYNOPSIS

C/C++:

```c
void shmem_barrier(int PE_start, int logPE_stride, int PE_size, long *pSync);
```

FORTRAN:

```fortran
INTEGER PE_start, logPE_stride, PE_size
INTEGER pSync(SHMEM_BARRIER_SYNC_SIZE)
CALL SHMEM_BARRIER(PE_start, logPE_stride, PE_size, pSync)
```

DESCRIPTION

Arguments

IN	*PE_start*	The lowest PE number of the *Active set* of PEs. *PE_start* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*logPE_stride*	The log (base 2) of the stride between consecutive PE numbers in the *Active set*. *logPE_stride* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*PE_size*	The number of PEs in the *Active set*. *PE_size* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*pSync*	A symmetric work array. In *C/C++*, *pSync* must be of type long and size *SHMEM_BARRIER_SYNC_SIZE*. In *Fortran*, *pSync* must be of type integer and size *SHMEM_BARRIER_SYNC_SIZE*. If you are using *Fortran*, it must be a default integer type. Every element of this array must be initialized to *SHMEM_SYNC_VALUE* before any of the PEs in the *Active set* enter *shmem_barrier* the first time.

API description

shmem_barrier is a collective synchronization routine over an *Active set*. Control returns from *shmem_barrier* after all PEs in the *Active set* (specified by *PE_start*, *logPE_stride*, and *PE_size*) have called *shmem_barrier*.

As with all OpenSHMEM collective routines, each of these routines assumes that only PEs in the *Active set* call the routine. If a PE not in the *Active set* calls an OpenSHMEM collective routine, undefined behavior results.

The values of arguments *PE_start*, *logPE_stride*, and *PE_size* must be equal on all PEs in the *Active set*. The same work array must be passed in *pSync* to all PEs in the *Active set*.

shmem_barrier ensures that all previously issued stores and remote memory updates, including AMOs and RMA operations, done by any of the PEs in the *Active set* are complete before returning.

The same *pSync* array may be reused on consecutive calls to *shmem_barrier* if the same active PE set is used.

Return Values

None.

Notes

If the *pSync* array is initialized at run time, be sure to use some type of synchronization, for example, a call to *shmem_barrier_all*, before calling *shmem_barrier* for the first time.

If the *Active set* does not change, *shmem_barrier* can be called repeatedly with the same *pSync* array. No additional synchronization beyond that implied by *shmem_barrier* itself is necessary in this case.

EXAMPLES

The following barrier example is for *C/C++* programs:

```
#include <stdio.h>
#include <shmem.h>

long pSync[SHMEM_BARRIER_SYNC_SIZE];
int x = 10101;

int main(void)
{
   int i, me, npes;

   for (i = 0; i < SHMEM_BARRIER_SYNC_SIZE; i += 1){
      pSync[i] = SHMEM_SYNC_VALUE;
   }

   shmem_init();
   me = shmem_my_pe();
   npes = shmem_n_pes();

   if(me % 2 == 0){
      x = 1000 + me;
      /*put to next even PE in a circular fashion*/
      shmem_int_p(&x, 4, (me+2)%npes);
      /*synchronize all even pes*/
      shmem_barrier(0, 1, (npes/2 + npes%2), pSync);
   }
   printf("%d: x = %d\n", me, x);
   return 0;
}
```

8.6.3 SHMEM_BROADCAST

Broadcasts a block of data from one PE to one or more destination PEs.

SYNOPSIS

C/C++:

```
void shmem_broadcast32(void *dest, const void *source, size_t nelems, int PE_root, int
    PE_start, int logPE_stride, int PE_size, long *pSync);
void shmem_broadcast64(void *dest, const void *source, size_t nelems, int PE_root, int
    PE_start, int logPE_stride, int PE_size, long *pSync);
```

FORTRAN:

```
INTEGER nelems, PE_root, PE_start, logPE_stride, PE_size
INTEGER pSync(SHMEM_BCAST_SYNC_SIZE)
CALL SHMEM_BROADCAST4(dest, source, nelems, PE_root, PE_start, logPE_stride, PE_size, pSync)
CALL SHMEM_BROADCAST8(dest, source, nelems, PE_root, PE_start, logPE_stride, PE_size, pSync)
CALL SHMEM_BROADCAST32(dest, source, nelems, PE_root, PE_start, logPE_stride, PE_size,pSync)
CALL SHMEM_BROADCAST64(dest, source, nelems, PE_root, PE_start, logPE_stride, PE_size,pSync)
```

DESCRIPTION

Arguments

OUT	*dest*	A symmetric data object.
IN	*source*	A symmetric data object that can be of any data type that is permissible for the *dest* argument.
IN	*nelems*	The number of elements in *source*. For *shmem_broadcast32* and *shmem_broadcast4*, this is the number of 32-bit halfwords. nelems must be of type *size_t* in *C*. If you are using *Fortran*, it must be a default integer value.
IN	*PE_root*	Zero-based ordinal of the PE, with respect to the *Active set*, from which the data is copied. Must be greater than or equal to 0 and less than *PE_size*. *PE_root* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*PE_start*	The lowest PE number of the *Active set* of PEs. *PE_start* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*logPE_stride*	The log (base 2) of the stride between consecutive PE numbers in the *Active set*. *log_PE_stride* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*PE_size*	The number of PEs in the *Active set*. *PE_size* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*pSync*	A symmetric work array. In *C/C++*, *pSync* must be of type long and size *SHMEM_BCAST_SYNC_SIZE*. In *Fortran*, *pSync* must be of type integer and size *SHMEM_BCAST_SYNC_SIZE*. Every element of this array must be initialized with the value *SHMEM_SYNC_VALUE* (in *C/C++*) or *SHMEM_SYNC_VALUE* (in *Fortran*) before any of the PEs in the *Active set* enter *shmem_broadcast*.

API description

OpenSHMEM broadcast routines are collective routines. They copy data object *source* on the processor specified by *PE_root* and store the values at *dest* on the other PEs specified by the triplet *PE_start*, *logPE_stride*, *PE_size*. The data is not copied to the *dest* area on the root PE.

As with all OpenSHMEM collective routines, each of these routines assumes that only PEs in the *Active set* call the routine. If a PE not in the *Active set* calls an OpenSHMEM collective routine, undefined behavior results.

The values of arguments *PE_root*, *PE_start*, *logPE_stride*, and *PE_size* must be equal on all PEs in the *Active set*. The same *dest* and *source* data objects and the same *pSync* work array must be passed to all PEs in the *Active set*.

Before any PE calls a broadcast routine, you must ensure that the following conditions exist (synchronization via a barrier or some other method is often needed to ensure this): The *pSync* array on all PEs in the *Active set* is not still in use from a prior call to a broadcast routine. The *dest* array on all PEs in the *Active set* is ready to accept the broadcast data.

Upon return from a broadcast routine, the following are true for the local PE: If the current PE is not the root PE, the *dest* data object is updated. The values in the *pSync* array are restored to the original values.

The *dest* and *source* data objects must conform to certain typing constraints, which are as follows:

Routine	Data type of *dest* and *source*
shmem_broadcast8, shmem_broadcast64	Any noncharacter type that has an element size of *64* bits. No *Fortran* derived types or *C/C++* structures are allowed.
shmem_broadcast4, shmem_broadcast32	Any noncharacter type that has an element size of *32* bits. No *Fortran* derived types or *C/C++* structures are allowed.

Return Values

None.

Notes

All OpenSHMEM broadcast routines restore *pSync* to its original contents. Multiple calls to OpenSHMEM routines that use the same *pSync* array do not require that *pSync* be reinitialized after the first call.

You must ensure the that the *pSync* array is not being updated by any PE in the *Active set* while any of the PEs participates in processing of an OpenSHMEM broadcast routine. Be careful to avoid these situations: If the *pSync* array is initialized at run time, some type of synchronization is needed to ensure that all PEs in the *Active set* have initialized *pSync* before any of them enter an OpenSHMEM routine called with the *pSync* synchronization array. A *pSync* array may be reused on a subsequent OpenSHMEM broadcast routine only if none of the PEs in the *Active set* are still processing a prior OpenSHMEM broadcast routine call that used the same *pSync* array. In general, this can be ensured only by doing some type of synchronization.

EXAMPLES

In the following examples, the call to *shmem_broadcast64* copies *source* on PE 4 to *dest* on PEs 5, 6, and 7.

C/C++ example:

```
#include <stdio.h>
#include <stdlib.h>
#include <shmem.h>

#define NUM_ELEMS 4
long pSync[SHMEM_BCAST_SYNC_SIZE];
long source[NUM_ELEMS], dest[NUM_ELEMS];

int main(void)
{
   int i, me, npes;

   shmem_init();
   me = shmem_my_pe();
   npes = shmem_n_pes();

   if (me == 0)
      for (i = 0; i < NUM_ELEMS; i++)
         source[i] = i;
```

```
   for (i=0; i < SHMEM_BCAST_SYNC_SIZE; i++) {
      pSync[i] = SHMEM_SYNC_VALUE;
   }
   shmem_barrier_all(); /* Wait for all PEs to initialize pSync */

   shmem_broadcast64(dest, source, NUM_ELEMS, 0, 0, 0, npes, pSync);
   printf("%d: %ld", me, dest[0]);
   for (i = 1; i < NUM_ELEMS; i++)
      printf(", %ld", dest[i]);
   printf("\n");
   return 0;
}
```

Fortran example:

```
INCLUDE "shmem.fh"

INTEGER PSYNC(SHMEM_BCAST_SYNC_SIZE)
INTEGER DEST, SOURCE, NLONG, PE_ROOT, PE_START,
&   LOGPE_STRIDE, PE_SIZE, PSYNC
COMMON /COM/ DEST, SOURCE

DATA PSYNC /SHMEM_BCAST_SYNC_SIZE*SHMEM_SYNC_VALUE/

CALL SHMEM_BROADCAST64(DEST, SOURCE, NLONG, 0, 4, 0, 4, PSYNC)
```

8.6.4 SHMEM_COLLECT, SHMEM_FCOLLECT

Concatenates blocks of data from multiple PEs to an array in every PE.

SYNOPSIS

C/C++:

```
void shmem_collect32(void *dest, const void *source, size_t nelems, int PE_start, int
    logPE_stride, int PE_size, long *pSync);
void shmem_collect64(void *dest, const void *source, size_t nelems, int PE_start, int
    logPE_stride, int PE_size, long *pSync);
void shmem_fcollect32(void *dest, const void *source, size_t nelems, int PE_start, int
    logPE_stride, int PE_size, long *pSync);
void shmem_fcollect64(void *dest, const void *source, size_t nelems, int PE_start, int
    logPE_stride, int PE_size, long *pSync);
```

FORTRAN:

```
INTEGER nelems
INTEGER PE_start, logPE_stride, PE_size
INTEGER pSync(SHMEM_COLLECT_SYNC_SIZE)
CALL SHMEM_COLLECT4(dest, source, nelems, PE_start, logPE_stride, PE_size, pSync)
CALL SHMEM_COLLECT8(dest, source, nelems, PE_start, logPE_stride, PE_size, pSync)
CALL SHMEM_COLLECT32(dest, source, nelems, PE_start, logPE_stride, PE_size, pSync)
CALL SHMEM_COLLECT64(dest, source, nelems, PE_start, logPE_stride, PE_size, pSync)
CALL SHMEM_FCOLLECT4(dest, source, nelems, PE_start, logPE_stride, PE_size, pSync)
CALL SHMEM_FCOLLECT8(dest, source, nelems, PE_start, logPE_stride, PE_size, pSync)
CALL SHMEM_FCOLLECT32(dest, source, nelems, PE_start, logPE_stride, PE_size, pSync)
CALL SHMEM_FCOLLECT64(dest, source, nelems, PE_start, logPE_stride, PE_size, pSync)
```

DESCRIPTION

Arguments

OUT	*dest*	A symmetric array. The *dest* argument must be large enough to accept the concatenation of the *source* arrays on all PEs. The data types are as follows: For *shmem_collect8*, *shmem_collect64*, *shmem_fcollect8*, and *shmem_fcollect64*, any data type with an element size of 64 bits. *Fortran* derived types, *Fortran* character type, and *C/C++* structures are not permitted. For *shmem_collect4*, *shmem_collect32*, *shmem_fcollect4*, and *shmem_fcollect32*, any data type with an element size of *32* bits. *Fortran* derived types, *Fortran* character type, and *C/C++* structures are not permitted.
IN	*source*	A symmetric data object that can be of any type permissible for the *dest* argument.
IN	*nelems*	The number of elements in the *source* array. *nelems* must be of type *size_t* for *C*. If you are using *Fortran*, it must be a default integer value.
IN	*PE_start*	The lowest PE number of the *Active set* of PEs. *PE_start* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*logPE_stride*	The log (base *2*) of the stride between consecutive PE numbers in the *Active set*. *logPE_stride* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*PE_size*	The number of PEs in the *Active set*. *PE_size* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*pSync*	A symmetric work array. In *C/C++*, *pSync* must be of type long and size *SHMEM_COLLECT_SYNC_SIZE*. In *Fortran*, *pSync* must be of type integer and size *SHMEM_COLLECT_SYNC_SIZE*. If you are using *Fortran*, it must be a default integer value. Every element of this array must be initialized with the value *SHMEM_SYNC_VALUE* in *C/C++* or *SHMEM_SYNC_VALUE* in *Fortran* before any of the PEs in the *Active set* enter *shmem_collect* or *shmem_fcollect*.

API description

OpenSHMEM collect and *fcollect* routines concatenate *nelems* *64*-bit or *32*-bit data items from the *source* array into the *dest* array, over the set of PEs defined by *PE_start*, *log2PE_stride*, and *PE_size*, in processor number order. The resultant *dest* array contains the contribution from PE *PE_start* first, then the contribution from PE *PE_start* + *PE_stride* second, and so on. The collected result is written to the *dest* array for all PEs in the *Active set*.

The *fcollect* routines require that *nelems* be the same value in all participating PEs, while the *collect* routines allow *nelems* to vary from PE to PE.

As with all OpenSHMEM collective routines, each of these routines assumes that only PEs in the *Active set* call the routine. If a PE not in the *Active set* and calls this collective routine, the behavior is undefined.

The values of arguments *PE_start*, *logPE_stride*, and *PE_size* must be equal on all PEs in the *Active set*. The same *dest* and *source* arrays and the same *pSync* work array must be passed to all PEs in the *Active set*.

Upon return from a collective routine, the following are true for the local PE: The *dest* array is updated. The values in the *pSync* array are restored to the original values.

Return Values

None.

Notes

All OpenSHMEM collective routines reset the values in *pSync* before they return, so a particular *pSync* buffer need only be initialized the first time it is used.

You must ensure that the *pSync* array is not being updated on any PE in the *Active set* while any of the PEs participate in processing of an OpenSHMEM collective routine. Be careful to avoid these situations: If the *pSync* array is initialized at run time, some type of synchronization is needed to ensure that all PEs in the working set have initialized *pSync* before any of them enter an OpenSHMEM routine called with the *pSync* synchronization array. A *pSync* array can be reused on a subsequent OpenSHMEM collective routine only if none of the PEs in the *Active set* are still processing a prior OpenSHMEM collective routine call that used the same *pSync* array. In general, this may be ensured only by doing some type of synchronization.

The collective routines operate on active PE sets that have a non-power-of-two *PE_size* with some performance degradation. They operate with no performance degradation when *nelems* is a non-power-of-two value.

EXAMPLES

The following *shmem_collect* example is for *C/C++* programs:

```
#include <stdio.h>
#include <stdlib.h>
#include <shmem.h>

long pSync[SHMEM_COLLECT_SYNC_SIZE];
int source[2];

int main(void)
{
   int i, me, npes;
   int *dest;

   shmem_init();
   me = shmem_my_pe();
   npes = shmem_n_pes();

   source[0] = me * 2;
   source[1] = me * 2 + 1;
   dest = (int *)shmem_malloc(sizeof(int) * npes * 2);
   for (i=0; i < SHMEM_COLLECT_SYNC_SIZE; i++) {
      pSync[i] = SHMEM_SYNC_VALUE;
   }
   shmem_barrier_all(); /* Wait for all PEs to initialize pSync */

   shmem_collect32(dest, source, 2, 0, 0, npes, pSync);
   printf("%d: %d", me, dest[0]);
   for (i = 1; i < npes * 2; i++)
      printf(", %d", dest[i]);
   printf("\n");
   return 0;
}
```

The following *SHMEM_COLLECT* example is for *Fortran* programs:

```
INCLUDE "shmem.fh"

INTEGER PSYNC(SHMEM_COLLECT_SYNC_SIZE)
DATA PSYNC /SHMEM_COLLECT_SYNC_SIZE*SHMEM_SYNC_VALUE/

CALL SHMEM_COLLECT4(DEST, SOURCE, 64, PE_START, LOGPE_STRIDE,
&  PE_SIZE, PSYNC)
```

8.6.5 SHMEM_REDUCTIONS

Performs arithmetic and logical operations across a set of PEs.

SYNOPSIS

AND
Performs a bitwise AND function across a set of processing elements (PEs).
C/C++:
```
void shmem_int_and_to_all(int *dest, const int *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, int *pWrk, long *pSync);
void shmem_long_and_to_all(long *dest, const long *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, long *pWrk, long *pSync);
void shmem_longlong_and_to_all(long long *dest, const long long *source, int nreduce, int
    PE_start, int logPE_stride, int PE_size, long long *pWrk, long *pSync);
void shmem_short_and_to_all(short *dest, const short *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, short *pWrk, long *pSync);
```
FORTRAN:
```
CALL SHMEM_INT4_AND_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_INT8_AND_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
```

MAX
Performs a maximum function reduction across a set of processing elements (PEs).
C/C++:
```
void shmem_double_max_to_all(double *dest, const double *source, int nreduce, int PE_start,
    int logPE_stride, int PE_size, double *pWrk, long *pSync);
void shmem_float_max_to_all(float *dest, const float *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, float *pWrk, long *pSync);
void shmem_int_max_to_all(int *dest, const int *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, int *pWrk, long *pSync);
void shmem_long_max_to_all(long *dest, const long *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, long *pWrk, long *pSync);
void shmem_longdouble_max_to_all(long double *dest, const long double *source, int nreduce,
    int PE_start, int logPE_stride, int PE_size, long double *pWrk, long *pSync);
void shmem_longlong_max_to_all(long long *dest, const long long *source, int nreduce, int
    PE_start, int logPE_stride, int PE_size, long long *pWrk, long *pSync);
void shmem_short_max_to_all(short *dest, const short *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, short *pWrk, long *pSync);
```
FORTRAN:
```
CALL SHMEM_INT4_MAX_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_INT8_MAX_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_REAL4_MAX_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_REAL8_MAX_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_REAL16_MAX_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
```

MIN
Performs a minimum function reduction across a set of processing elements (PEs).
C/C++:
```
void shmem_double_min_to_all(double *dest, const double *source, int nreduce, int PE_start,
    int logPE_stride, int PE_size, double *pWrk, long *pSync);
void shmem_float_min_to_all(float *dest, const float *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, float *pWrk, long *pSync);
```

```
void shmem_int_min_to_all(int *dest, const int *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, int *pWrk, long *pSync);
void shmem_long_min_to_all(long *dest, const long *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, long *pWrk, long *pSync);
void shmem_longdouble_min_to_all(long double *dest, const long double *source, int nreduce,
    int PE_start, int logPE_stride, int PE_size, long double *pWrk, long *pSync);
void shmem_longlong_min_to_all(long long *dest, const long long *source, int nreduce, int
    PE_start, int logPE_stride, int PE_size, long long *pWrk, long *pSync);
void shmem_short_min_to_all(short *dest, const short *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, short *pWrk, long *pSync);
```

FORTRAN:

```
CALL SHMEM_INT4_MIN_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_INT8_MIN_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_REAL4_MIN_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_REAL8_MIN_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_REAL16_MIN_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
```

SUM

Performs a sum reduction across a set of processing elements (PEs).

C/C++:

```
void shmem_complexd_sum_to_all(double complex *dest, const double complex *source, int
    nreduce, int PE_start, int logPE_stride, int PE_size, double complex *pWrk, long
    *pSync);
void shmem_complexf_sum_to_all(float complex *dest, const float complex *source, int nreduce,
     int PE_start, int logPE_stride, int PE_size, float complex *pWrk, long *pSync);
void shmem_double_sum_to_all(double *dest, const double *source, int nreduce, int PE_start,
    int logPE_stride, int PE_size, double *pWrk, long *pSync);
void shmem_float_sum_to_all(float *dest, const float *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, float *pWrk, long *pSync);
void shmem_int_sum_to_all(int *dest, const int *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, int *pWrk, long *pSync);
void shmem_long_sum_to_all(long *dest, const long *source, int nreduce, int PE_start, int
    logPE_stride,int PE_size, long *pWrk, long *pSync);
void shmem_longdouble_sum_to_all(long double *dest, const long double *source, int nreduce,
    int PE_start, int logPE_stride, int PE_size, long double *pWrk, long *pSync);
void shmem_longlong_sum_to_all(long long *dest, const long long *source, int nreduce, int
    PE_start, int logPE_stride, int PE_size, long long *pWrk, long *pSync);
void shmem_short_sum_to_all(short *dest, const short *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, short *pWrk, long *pSync);
```

FORTRAN:

```
CALL SHMEM_COMP4_SUM_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_COMP8_SUM_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_INT4_SUM_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_INT8_SUM_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
```

```
CALL SHMEM_REAL4_SUM_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_REAL8_SUM_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_REAL16_SUM_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
```

PROD
Performs a product reduction across a set of processing elements (PEs).
C/C++:

```
void shmem_complexd_prod_to_all(double complex *dest, const double complex *source, int
    nreduce, int PE_start, int logPE_stride, int PE_size, double complex *pWrk, long
    *pSync);
void shmem_complexf_prod_to_all(float complex *dest, const float complex *source, int
    nreduce, int PE_start, int logPE_stride, int PE_size, float complex *pWrk, long *pSync);
void shmem_double_prod_to_all(double *dest, const double *source, int nreduce, int PE_start,
    int logPE_stride, int PE_size, double *pWrk, long *pSync);
void shmem_float_prod_to_all(float *dest, const float *source, int nreduce, int PE_start, int
     logPE_stride, int PE_size, float *pWrk, long *pSync);
void shmem_int_prod_to_all(int *dest, const int *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, int *pWrk, long *pSync);
void shmem_long_prod_to_all(long *dest, const long *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, long *pWrk, long *pSync);
void shmem_longdouble_prod_to_all(long double *dest, const long double *source, int nreduce,
    int PE_start, int logPE_stride, int PE_size, long double *pWrk, long *pSync);
void shmem_longlong_prod_to_all(long long *dest, const long long *source, int nreduce, int
    PE_start, int logPE_stride, int PE_size, long long *pWrk, long *pSync);
void shmem_short_prod_to_all(short *dest, const short *source, int nreduce, int PE_start, int
     logPE_stride, int PE_size, short *pWrk, long *pSync);
```

FORTRAN:

```
CALL SHMEM_COMP4_PROD_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_COMP8_PROD_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_INT4_PROD_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_INT8_PROD_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_REAL4_PROD_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_REAL8_PROD_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_REAL16_PROD_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
```

OR
Performs a bitwise OR function reduction across a set of processing elements (PEs).
C/C++:

```
void shmem_int_or_to_all(int *dest, const int *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, int *pWrk, long *pSync);
void shmem_long_or_to_all(long *dest, const long *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, long *pWrk, long *pSync);
void shmem_longlong_or_to_all(long long *dest, const long long *source, int nreduce, int
    PE_start, int logPE_stride, int PE_size, long long *pWrk, long *pSync);
```

```
void shmem_short_or_to_all(short *dest, const short *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, short *pWrk, long *pSync);
```

FORTRAN:

```
CALL SHMEM_INT4_OR_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_INT8_OR_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
```

XOR

Performs a bitwise EXCLUSIVE OR reduction across a set of processing elements (PEs).

C/C++:

```
void shmem_int_xor_to_all(int *dest, const int *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, int *pWrk, long *pSync);
void shmem_long_xor_to_all(long *dest, const long *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, long *pWrk, long *pSync);
void shmem_longlong_xor_to_all(long long *dest, const long long *source, int nreduce, int
    PE_start, int logPE_stride, int PE_size, long long *pWrk, long *pSync);
void shmem_short_xor_to_all(short *dest, const short *source, int nreduce, int PE_start, int
    logPE_stride, int PE_size, short *pWrk, long *pSync);
```

FORTRAN:

```
CALL SHMEM_INT4_XOR_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
CALL SHMEM_INT8_XOR_TO_ALL(dest, source, nreduce, PE_start, logPE_stride, PE_size, pWrk,
    pSync)
```

DESCRIPTION

Arguments

IN	*dest*	A symmetric array, of length *nreduce* elements, to receive the result of the reduction routines. The data type of *dest* varies with the version of the reduction routine being called. When calling from *C/C++*, refer to the SYNOPSIS section for data type information.
IN	*source*	A symmetric array, of length *nreduce* elements, that contains one element for each separate reduction routine. The *source* argument must have the same data type as *dest*.
IN	*nreduce*	The number of elements in the *dest* and *source* arrays. *nreduce* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*PE_start*	The lowest PE number of the *Active set* of PEs. *PE_start* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*logPE_stride*	The log (base 2) of the stride between consecutive PE numbers in the *Active set*. *logPE_stride* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*PE_size*	The number of PEs in the *Active set*. *PE_size* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*pWrk*	A symmetric work array. The *pWrk* argument must have the same data type as *dest*. In *C/C++*, this contains max(*nreduce*/2 + 1, *SHMEM_REDUCE_MIN_WRKDATA_SIZE*) elements. In *Fortran*, this contains max(*nreduce*/2 + 1, *SHMEM_REDUCE_MIN_WRKDATA_SIZE*) elements.

IN	*pSync*	A symmetric work array. In *C/C++*, *pSync* must be of type long and size *SHMEM_REDUCE_SYNC_SIZE*. In *Fortran*, *pSync* must be of type integer and size *SHMEM_REDUCE_SYNC_SIZE*. If you are using *Fortran*, it must be a default integer value. Every element of this array must be initialized with the value *SHMEM_SYNC_VALUE* (in *C/C++*) or *SHMEM_SYNC_VALUE* (in *Fortran*) before any of the PEs in the *Active set* enter the reduction routine.

API description

OpenSHMEM reduction routines compute one or more reductions across symmetric arrays on multiple PEs. A reduction performs an associative binary routine across a set of values.

The *nreduce* argument determines the number of separate reductions to perform. The *source* array on all PEs in the *Active set* provides one element for each reduction. The results of the reductions are placed in the *dest* array on all PEs in the *Active set*. The *Active set* is defined by the *PE_start*, *logPE_stride*, *PE_size* triplet.

The *source* and *dest* arrays may be the same array, but they may not be overlapping arrays.

As with all OpenSHMEM collective routines, each of these routines assumes that only PEs in the *Active set* call the routine. If a PE not in the *Active set* calls an OpenSHMEM collective routine, undefined behavior results.

The values of arguments *nreduce*, *PE_start*, *logPE_stride*, and *PE_size* must be equal on all PEs in the *Active set*. The same *dest* and *source* arrays, and the same *pWrk* and *pSync* work arrays, must be passed to all PEs in the *Active set*.

Before any PE calls a reduction routine, you must ensure that the following conditions exist (synchronization via a *barrier* or some other method is often needed to ensure this): The *pWrk* and *pSync* arrays on all PEs in the *Active set* are not still in use from a prior call to a collective OpenSHMEM routine. The *dest* array on all PEs in the *Active set* is ready to accept the results of the *reduction*.

Upon return from a reduction routine, the following are true for the local PE: The *dest* array is updated. The values in the *pSync* array are restored to the original values.

When calling from *Fortran*, the *dest* date types are as follows:

Routine	Data type
shmem_int8_and_to_all	Integer, with an element size of 8 bytes.
shmem_int4_and_to_all	Integer, with an element size of 4 bytes.
shmem_comp8_max_to_all	Complex, with an element size equal to two 8-byte real values.
shmem_int4_max_to_all	Integer, with an element size of 4 bytes.
shmem_int8_max_to_all	Integer, with an element size of 8 bytes.
shmem_real4_max_to_all	Real, with an element size of 4 bytes.
shmem_real16_max_to_all	Real, with an element size of 16 bytes.
shmem_int4_min_to_all	Integer, with an element size of 4 bytes.
shmem_int8_min_to_all	Integer, with an element size of 8 bytes.
shmem_real4_min_to_all	Real, with an element size of 4 bytes.
shmem_real8_min_to_all	Real, with an element size of 8 bytes.
shmem_real16_min_to_all	Real,with an element size of 16 bytes.
shmem_comp4_sum_to_all	Complex, with an element size equal to two 4-byte real values.
shmem_comp8_sum_to_all	Complex, with an element size equal to two 8-byte real values.
shmem_int4_sum_to_all	Integer, with an element size of 4 bytes.
shmem_int8_sum_to_all	Integer, with an element size of 8 bytes..
shmem_real4_sum_to_all	Real, with an element size of 4 bytes.
shmem_real8_sum_to_all	Real, with an element size of 8 bytes.
shmem_real16_sum_to_all	Real, with an element size of 16 bytes.

shmem_comp4_prod_to_all	Complex, with an element size equal to two 4-byte real values.
shmem_comp8_prod_to_all	Complex, with an element size equal to two 8-byte real values.
shmem_int4_prod_to_all	Integer, with an element size of 4 bytes.
shmem_int8_prod_to_all	Integer, with an element size of 8 bytes.
shmem_real4_prod_to_all	Real, with an element size of 4 bytes.
shmem_real8_prod_to_all	Real, with an element size of 8 bytes.
shmem_real16_prod_to_all	Real, with an element size of 16 bytes.
shmem_int8_or_to_all	Integer, with an element size of 8 bytes.
shmem_int4_or_to_all	Integer, with an element size of 4 bytes.
shmem_int8_xor_to_all	Integer, with an element size of 8 bytes.
shmem_int4_xor_to_all	Integer, with an element size of 4 bytes.

Return Values

None.

Notes

All OpenSHMEM reduction routines reset the values in *pSync* before they return, so a particular *pSync* buffer need only be initialized the first time it is used. You must ensure that the *pSync* array is not being updated on any PE in the *Active set* while any of the PEs participate in processing of an OpenSHMEM reduction routine. Be careful to avoid the following situations: If the *pSync* array is initialized at run time, some type of synchronization is needed to ensure that all PEs in the working set have initialized *pSync* before any of them enter an OpenSHMEM routine called with the *pSync* synchronization array. A *pSync* or *pWrk* array can be reused in a subsequent reduction routine call only if none of the PEs in the *Active set* are still processing a prior reduction routine call that used the same *pSync* or *pWrk* arrays. In general, this can be assured only by doing some type of synchronization.

EXAMPLES

This *Fortran* reduction example statically initializes the *pSync* array and finds the logical *AND* of the integer variable *FOO* across all even PEs.

```
INCLUDE "shmem.fh"

INTEGER PSYNC(SHMEM_REDUCE_SYNC_SIZE)
DATA PSYNC /SHMEM_REDUCE_SYNC_SIZE*SHMEM_SYNC_VALUE/
PARAMETER (NR=1)
INTEGER*4 PWRK(MAX(NR/2+1,SHMEM_REDUCE_MIN_WRKDATA_SIZE))
INTEGER FOO, FOOAND
SAVE FOO, FOOAND, PWRK
INTRINSIC SHMEM_MY_PE()

FOO = SHMEM_MY_PE()
IF ( MOD(SHMEM_MY_PE() .EQ. 0) THEN
    IF ( MOD(SHMEM_N_PES()(),2) .EQ. 0) THEN
       CALL SHMEM_INT8_AND_TO_ALL(FOOAND, FOO, NR, 0, 1, NPES/2, &
   PWRK, PSYNC)
    ELSE
       CALL SHMEM_INT8_AND_TO_ALL(FOOAND, FOO, NR, 0, 1, NPES/2+1, &
   PWRK, PSYNC)

    ENDIF
    PRINT*,'Result on PE ',SHMEM_MY_PE(),' is ',FOOAND
ENDIF
```

This *Fortran* example statically initializes the *pSync* array and finds the *maximum* value of real variable *FOO* across all even PEs.

```
INCLUDE "shmem.fh"

INTEGER PSYNC(SHMEM_REDUCE_SYNC_SIZE)
DATA PSYNC /SHMEM_REDUCE_SYNC_SIZE*SHMEM_SYNC_VALUE/
PARAMETER (NR=1)
REAL FOO, FOOMAX, PWRK(MAX(NR/2+1,SHMEM_REDUCE_MIN_WRKDATA_SIZE))
COMMON /COM/ FOO, FOOMAX, PWRK
INTRINSIC SHMEM_MY_PE()

IF ( MOD(SHMEM_MY_PE() .EQ. 0) THEN
       CALL SHMEM_REAL8_MAX_TO_ALL(FOOMAX, FOO, NR, 0, 1, N$PES/2,
&  PWRK, PSYNC)
       PRINT*,'Result on PE ',SHMEM_MY_PE(),' is ',FOOMAX
ENDIF
```

This *Fortran* example statically initializes the *pSync* array and finds the *minimum* value of real variable *FOO* across all the even PEs.

```
INCLUDE "shmem.fh"

INTEGER PSYNC(SHMEM_REDUCE_SYNC_SIZE)
DATA PSYNC /SHMEM_REDUCE_SYNC_SIZE*SHMEM_SYNC_VALUE/
PARAMETER (NR=1)
REAL FOO, FOOMIN, PWRK(MAX(NR/2+1,SHMEM_REDUCE_MIN_WRKDATA_SIZE))
COMMON /COM/ FOO, FOOMIN, PWRK
INTRINSIC SHMEM_MY_PE()

IF ( MOD(SHMEM_MY_PE() .EQ. 0) THEN
       CALL SHMEM_REAL8_MIN_TO_ALL(FOOMIN, FOO, NR, 0, 1, N$PES/2,
&  PWRK, PSYNC)
       PRINT*,'Result on PE ',SHMEM_MY_PE(),' is ',FOOMIN
ENDIF
```

This *Fortran* example statically initializes the *pSync* array and finds the *sum* of the real variable *FOO* across all even PEs.

```
INCLUDE "shmem.fh"

INTEGER PSYNC(SHMEM_REDUCE_SYNC_SIZE)
DATA PSYNC /SHMEM_REDUCE_SYNC_SIZE*SHMEM_SYNC_VALUE/
PARAMETER (NR=1)
REAL FOO, FOOSUM, PWRK(MAX(NR/2+1,SHMEM_REDUCE_MIN_WRKDATA_SIZE))
COMMON /COM/ FOO, FOOSUM, PWRK
INTRINSIC SHMEM_MY_PE()

IF ( MOD(SHMEM_MY_PE() .EQ. 0) THEN
       CALL SHMEM_INT4_SUM_TO_ALL(FOOSUM, FOO, NR, 0, 1, N$PES/2,
&  PWRK, PSYNC)
       PRINT*,'Result on PE ',SHMEM_MY_PE(),' is ',FOOSUM
ENDIF
```

This *Fortran* example statically initializes the *pSync* array and finds the *product* of the real variable *FOO* across all the even PEs.

```
INCLUDE "shmem.fh"

INTEGER PSYNC(SHMEM_REDUCE_SYNC_SIZE)
DATA PSYNC /SHMEM_REDUCE_SYNC_SIZE*SHMEM_SYNC_VALUE/
PARAMETER (NR=1)
REAL FOO, FOOPROD, PWRK(MAX(NR/2+1,SHMEM_REDUCE_MIN_WRKDATA_SIZE))
COMMON /COM/ FOO, FOOPROD, PWRK
INTRINSIC SHMEM_MY_PE()

IF ( MOD(SHMEM_MY_PE() .EQ. 0) THEN
        CALL SHMEM_COMP8_PROD_TO_ALL(FOOPROD, FOO, NR, 0, 1, N$PES/2,
&  PWRK, PSYNC)
        PRINT*,'Result on PE ',SHMEM_MY_PE(),' is ',FOOPROD
ENDIF
```

This *Fortran* example statically initializes the *pSync* array and finds the logical *OR* of the integer variable *FOO* across all even PEs.

```
INCLUDE "shmem.fh"

INTEGER PSYNC(SHMEM_REDUCE_SYNC_SIZE)
DATA PSYNC /SHMEM_REDUCE_SYNC_SIZE*SHMEM_SYNC_VALUE/
PARAMETER (NR=1)
REAL PWRK(MAX(NR/2+1,SHMEM_REDUCE_MIN_WRKDATA_SIZE))
INTEGER FOO, FOOOR
COMMON /COM/ FOO, FOOOR, PWRK
INTRINSIC SHMEM_MY_PE()

IF ( MOD(SHMEM_MY_PE() .EQ. 0) THEN
        CALL SHMEM_INT8_OR_TO_ALL(FOOOR, FOO, NR, 0, 1, N$PES/2,
&  PWRK, PSYNC)
        PRINT*,'Result on PE ',SHMEM_MY_PE(),' is ',FOOOR
ENDIF
```

This *Fortran* example statically initializes the *pSync* array and computes the exclusive *XOR* of variable *FOO* across all even PEs.

```
INCLUDE "shmem.fh"

INTEGER PSYNC(SHMEM_REDUCE_SYNC_SIZE)
DATA PSYNC /SHMEM_REDUCE_SYNC_SIZE*SHMEM_SYNC_VALUE/
PARAMETER (NR=1)
REAL FOO, FOOXOR, PWRK(MAX(NR/2+1,SHMEM_REDUCE_MIN_WRKDATA_SIZE))
COMMON /COM/ FOO, FOOXOR, PWRK
INTRINSIC SHMEM_MY_PE()

IF ( MOD(SHMEM_MY_PE() .EQ. 0) THEN
       CALL SHMEM_REAL8_XOR_TO_ALL(FOOXOR, FOO, NR, 0, 1, N$PES/2,
&  PWRK, PSYNC)
       PRINT*,'Result on PE ',SHMEM_MY_PE(),' is ',FOOXOR
ENDIF
```

8.6.6 SHMEM_ALLTOALL

shmem_alltoall is a collective routine where each PE exchanges a fixed amount of data with all other PEs in the *Active set*.

SYNOPSIS

C/C++:

```
void shmem_alltoall32(void *dest, const void *source, size_t nelems, int PE_start, int
    logPE_stride, int PE_size, long *pSync);
void shmem_alltoall64(void *dest, const void *source, size_t nelems, int PE_start, int
    logPE_stride, int PE_size, long *pSync);
```

FORTRAN:

```
INTEGER pSync(SHMEM_ALLTOALL_SYNC_SIZE)
INTEGER PE_start, logPE_stride, PE_size, nelems
CALL SHMEM_ALLTOALL32(dest, source, nelems, PE_start, logPE_stride, PE_size, pSync)
CALL SHMEM_ALLTOALL64(dest, source, nelems, PE_start, logPE_stride, PE_size, pSync)
```

DESCRIPTION

Arguments

OUT	*dest*	A symmetric data object large enough to receive the combined total of *nelems* elements from each PE in the *Active set*.
IN	*source*	A symmetric data object that contains *nelems* elements of data for each PE in the *Active set*, ordered according to destination PE.
IN	*nelems*	The number of elements to exchange for each PE. *nelems* must be of type size_t for *C/C++*. If you are using *Fortran*, it must be a default integer value.
IN	*PE_start*	The lowest PE number of the *Active set* of PEs. *PE_start* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*logPE_stride*	The log (base 2) of the stride between consecutive PE numbers in the *Active set*. *logPE_stride* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*PE_size*	The number of PEs in the *Active set*. *PE_size* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*pSync*	A symmetric work array. In *C/C++*, *pSync* must be of type long and size *SHMEM_ALLTOALL_SYNC_SIZE*. In *Fortran*, *pSync* must be of type integer and size *SHMEM_ALLTOALL_SYNC_SIZE*. If you are using *Fortran*, it must be a default integer value. Every element of this array must be initialized with the value *SHMEM_SYNC_VALUE* before any of the PEs in the *Active set* enter the routine.

API description

The *shmem_alltoall* routines are collective routines. Each PE in the *Active set* exchanges *nelems* data elements of size 32 bits (for *shmem_alltoall32*) or 64 bits (for *shmem_alltoall64*) with all other PEs in the set. The data being sent and received are stored in a contiguous symmetric data object. The total size of each PEs *source* object and *dest* object is *nelems* times the size of an element (32 bits or 64 bits) times *PE_size*. The *source* object contains *PE_size* blocks of data (the size of each block defined by *nelems*) and each block of data is sent to a different PE. PE *i* sends the *j*th block of its *source* object to PE *j* and that block of data is placed in the *i*th block of the *dest* object of PE *j*.

As with all OpenSHMEM collective routines, this routine assumes that only PEs in the *Active set* call the routine. If a PE not in the *Active set* calls an OpenSHMEM collective routine, undefined behavior results.

The values of arguments *nelems*, *PE_start*, *logPE_stride*, and *PE_size* must be equal on all PEs in the *Active set*. The same *dest* and *source* data objects, and the same *pSync* work array must be passed to all PEs in the *Active set*.

Before any PE calls a *shmem_alltoall* routine, the following conditions must exist (synchronization via a barrier or some other method is often needed to ensure this): The *pSync* array on all PEs in the *Active set* is not still in use from a prior call to a *shmem_alltoall/s* routine. The *dest* data object on all PEs in the *Active set* is ready to accept the *shmem_alltoall* data.

Upon return from a *shmem_alltoall* routine, the following is true for the local PE: Its *dest* symmetric data object is completely updated and the data has been copied out of the *source* data object. The values in the *pSync* array are restored to the original values.

The *dest* and *source* data objects must conform to certain typing constraints, which are as follows:

Routine	Data type of *dest* and *source*
shmem_alltoall64	*64* bits aligned.
shmem_alltoall32	*32* bits aligned.

Return Values

None.

Notes

This routine restores *pSync* to its original contents. Multiple calls to OpenSHMEM routines that use the same *pSync* array do not require that *pSync* be reinitialized after the first call. You must ensure the that the *pSync* array is not being updated by any PE in the *Active set* while any of the PEs participates in processing of an OpenSHMEM *shmem_alltoall* routine. Be careful to avoid these situations: If the *pSync* array is initialized at run time, some type of synchronization is needed to ensure that all PEs in the *Active set* have initialized *pSync* before any of them enter an OpenSHMEM routine called with the *pSync* synchronization array. A *pSync* array may be reused on a subsequent OpenSHMEM *shmem_alltoall* routine only if none of the PEs in the *Active set* are still processing a prior OpenSHMEM *shmem_alltoall* routine call that used the same *pSync* array. In general, this can be ensured only by doing some type of synchronization.

EXAMPLES

This example shows a *shmem_alltoall64* on two long elements among all PEs.

```
#include <shmem.h>
#include <stdio.h>

long pSync[SHMEM_ALLTOALL_SYNC_SIZE];

int main(void)
{
    int64_t *source, *dest;
    int  i, count, pe;

    shmem_init();

    count = 2;
    dest = (int64_t*) shmem_malloc(count * shmem_n_pes() * sizeof(int64_t));
    source = (int64_t*) shmem_malloc(count * shmem_n_pes() * sizeof(int64_t));

    /* assign source values */
    for (pe=0; pe <shmem_n_pes(); pe++){
       for (i=0; i<count; i++){
          source[(pe*count)+i] = shmem_my_pe() + pe;
          dest[(pe*count)+i] = 9999;
       }
    }

    for (i=0; i< SHMEM_ALLTOALL_SYNC_SIZE; i++) {
       pSync[i] = SHMEM_SYNC_VALUE;
    }
    /* wait for all PEs to initialize pSync */
    shmem_barrier_all();

    /* alltoall on all PES */
    shmem_alltoall64(dest, source, count, 0, 0, shmem_n_pes(), pSync);

    /* verify results */
    for (pe=0; pe<shmem_n_pes(); pe++) {
       for (i=0; i<count; i++){
          if (dest[(pe*count)+i] != shmem_my_pe() + pe) {
          printf("[%d] ERROR: dest[%d]=%ld, should be %d\n",
                   shmem_my_pe(),(pe*count)+i,dest[(pe*count)+i],
                   shmem_n_pes() + pe);
            }
        }
    }

    shmem_barrier_all();
```

```
    shmem_free(dest);
    shmem_free(source);
    shmem_finalize();
    return 0;
}
```

8.6.7 SHMEM_ALLTOALLS

shmem_alltoalls is a collective routine where each PE exchanges a fixed amount of strided data with all other PEs in the *Active set*.

SYNOPSIS

C/C++:

```
void shmem_alltoalls32(void *dest, const void *source, ptrdiff_t dst, ptrdiff_t sst, size_t
    nelems, int PE_start, int logPE_stride, int PE_size, long *pSync);
void shmem_alltoalls64(void *dest, const void *source, ptrdiff_t dst, ptrdiff_t sst, size_t
    nelems, int PE_start, int logPE_stride, int PE_size, long *pSync);
```

FORTRAN:

```
INTEGER pSync(SHMEM_ALLTOALLS_SYNC_SIZE)
INTEGER dst, sst, PE_start, logPE_stride, PE_size
INTEGER nelems
CALL SHMEM_ALLTOALLS32(dest, source, dst, sst, nelems, PE_start, logPE_stride, PE_size, pSync
    )
CALL SHMEM_ALLTOALLS64(dest, source, dst, sst, nelems, PE_start, logPE_stride, PE_size, pSync
    )
```

DESCRIPTION

Arguments

OUT	*dest*	A symmetric data object large enough to receive the combined total of *nelems* elements from each PE in the *Active set*.
IN	*source*	A symmetric data object that contains *nelems* elements of data for each PE in the *Active set*, ordered according to destination PE.
IN	*dst*	The stride between consecutive elements of the *dest* data object. The stride is scaled by the element size. A value of *1* indicates contiguous data. *dst* must be of type *ptrdiff_t*. If you are using *Fortran*, it must be a default integer value.
IN	*sst*	The stride between consecutive elements of the *source* data object. The stride is scaled by the element size. A value of *1* indicates contiguous data. *sst* must be of type *ptrdiff_t*. If you are using *Fortran*, it must be a default integer value.
IN	*nelems*	The number of elements to exchange for each PE. *nelems* must be of type size_t for *C/C++*. If you are using *Fortran*, it must be a default integer value.
IN	*PE_start*	The lowest PE number of the *Active set* of PEs. *PE_start* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*logPE_stride*	The log (base 2) of the stride between consecutive PE numbers in the *Active set*. *logPE_stride* must be of type integer. If you are using *Fortran*, it must be a default integer value.
IN	*PE_size*	The number of PEs in the *Active set*. *PE_size* must be of type integer. If you are using *Fortran*, it must be a default integer value.

IN	*pSync*	A symmetric work array. In *C/C++*, *pSync* must be of type long and size *SHMEM_ALLTOALLS_SYNC_SIZE*. In *Fortran*, *pSync* must be of type integer and size *SHMEM_ALLTOALLS_SYNC_SIZE*. If you are using *Fortran*, it must be a default integer value. Every element of this array must be initialized with the value *SHMEM_SYNC_VALUE* before any of the PEs in the *Active set* enter the routine.

API description

The *shmem_alltoalls* routines are collective routines. Each PE in the *Active set* exchanges *nelems* strided data elements of size 32 bits (for *shmem_alltoalls32*) or 64 bits (for *shmem_alltoalls64*) with all other PEs in the set. Both strides, *dst* and *sst*, must be greater than or equal to *1*. The *sst**jth block sent from PE *i* to PE *j* is placed in the *dst**ith block of the *dest* data object on PE *j*.

As with all OpenSHMEM collective routines, these routines assume that only PEs in the *Active set* call the routine. If a PE not in the *Active set* calls an OpenSHMEM collective routine, undefined behavior results.

The values of arguments *dst*, *sst*, *nelems*, *PE_start*, *logPE_stride*, and *PE_size* must be equal on all PEs in the *Active set*. The same *dest* and *source* data objects, and the same *pSync* work array must be passed to all PEs in the *Active set*.

Before any PE calls to a *shmem_alltoalls* routine, the following conditions must exist (synchronization via a barrier or some other method is often needed to ensure this): The *pSync* array on all PEs in the *Active set* is not still in use from a prior call to a *shmem_alltoalls* routine. The *dest* data object on all PEs in the *Active set* is ready to accept the *shmem_alltoalls* data.

Upon return from a *shmem_alltoalls* routine, the following is true for the local PE: Its *dest* symmetric data object is completely updated and the data has been copied out of the *source* data object. The values in the *pSync* array are restored to the original values.

The *dest* and *source* data objects must conform to certain typing constraints, which are as follows:

Routine	Data type of *dest* and *source*
shmem_alltoalls64	*64* bits aligned.
shmem_alltoalls32	*32* bits aligned.

Return Values

None.

Notes

This routine restores *pSync* to its original contents. Multiple calls to OpenSHMEM routines that use the same *pSync* array do not require that *pSync* be reinitialized after the first call. You must ensure the that the *pSync* array is not being updated by any PE in the *Active set* while any of the PEs participates in processing of an OpenSHMEM *shmem_alltoalls* routine. Be careful to avoid these situations: If the *pSync* array is initialized at run time, some type of synchronization is needed to ensure that all PEs in the *Active set* have initialized *pSync* before any of them enter an OpenSHMEM routine called with the *pSync* synchronization array. A *pSync* array may be reused on a subsequent OpenSHMEM *shmem_alltoalls* routine only if none of the PEs in the *Active set* are still processing a prior OpenSHMEM *shmem_alltoalls* routine call that used the same *pSync* array. In general, this can be ensured only by doing some type of synchronization.

EXAMPLES

This example shows a *shmem_alltoalls64* on two long elements among all PEs.

```
#include <shmem.h>
#include <stdio.h>

long pSync[SHMEM_ALLTOALLS_SYNC_SIZE];

int main(void)
{
    int64_t *source, *dest;
    int  i, count, pe;

    shmem_init();

    count = 2;
    dest = (int64_t*) shmem_malloc(count * shmem_n_pes() * sizeof(int64_t));
    source = (int64_t*) shmem_malloc(count * shmem_n_pes() * sizeof(int64_t));

    /* assign source values */
    for (pe=0; pe <shmem_n_pes(); pe++){
       for (i=0; i<count; i++){
          source[(pe*count)+i] = shmem_my_pe() + pe;
          dest[(pe*count)+i] = 9999;
       }
    }

    for (i=0; i< SHMEM_ALLTOALLS_SYNC_SIZE; i++) {
       pSync[i] = SHMEM_SYNC_VALUE;
    }
    /* wait for all PEs to initialize pSync */
    shmem_barrier_all();

    /* alltoalls on all PES */
    shmem_alltoalls64(dest, source, 1, 1, count, 0, 0, shmem_n_pes(), pSync);

    /* verify results */
    for (pe=0; pe<shmem_n_pes(); pe++) {
       for (i=0; i<count; i++){
          if (dest[(pe*count)+i] != shmem_my_pe() + pe) {
          printf("[%d] ERROR: dest[%d]=%ld, should be %d\n",
                  shmem_my_pe(),(pe*count)+i,dest[(pe*count)+i],
                  shmem_n_pes() + pe);
            }
        }
    }

    shmem_barrier_all();
    shmem_free(dest);
    shmem_free(source);
    shmem_finalize();
    return 0;
}
```

8.7 Point-To-Point Synchronization Routines

The following section discusses OpenSHMEM APIs that provides a mechanism for synchronization between two PEs based on the value of a symmetric data object.

8.7.1 SHMEM_WAIT

Wait for a variable on the local PE to change.

SYNOPSIS

C/C++:

```
void shmem_int_wait(volatile int *ivar, int cmp_value);
void shmem_int_wait_until(volatile int *ivar, int cmp, int cmp_value);
void shmem_long_wait(volatile long *ivar, long cmp_value);
void shmem_long_wait_until(volatile long *ivar, int cmp, long cmp_value);
void shmem_longlong_wait(volatile long long *ivar, long long cmp_value);
void shmem_longlong_wait_until(volatile long long *ivar, int cmp, long long cmp_value);
void shmem_short_wait(volatile short *ivar, short cmp_value);
void shmem_short_wait_until(volatile short *ivar, int cmp, short cmp_value);
void shmem_wait(volatile long *ivar, long cmp_value);
void shmem_wait_until(volatile long *ivar, int cmp, long cmp_value);
```

FORTRAN:

```
CALL SHMEM_INT4_WAIT(ivar, cmp_value)
CALL SHMEM_INT4_WAIT_UNTIL(ivar, cmp, cmp_value)
CALL SHMEM_INT8_WAIT(ivar, cmp_value)
CALL SHMEM_INT8_WAIT_UNTIL(ivar, cmp, cmp_value)
CALL SHMEM_WAIT(ivar, cmp_value)
CALL SHMEM_WAIT_UNTIL(ivar, cmp, cmp_value)
```

DESCRIPTION

Arguments

OUT	*ivar*	A remotely accessible integer variable that is being updated by another PE. If you are using *C/C++*, the type of *ivar* should match that implied in the SYNOPSIS section.
IN	*cmp*	The compare operator that compares *ivar* with *cmp_value*. *cmp* must be of type integer. If you are using *Fortran*, it must be of default kind. If you are using *C/C++*, the type of *cmp* should match that implied in the SYNOPSIS section.
IN	*cmp_value*	*cmp_value* must be of type integer. If you are using *C/C++*, the type of *cmp_value* should match that implied in the SYNOPSIS section. If you are using *Fortran*, cmp_value must be an integer of the same size and kind as *ivar*.

API description

shmem_wait and *shmem_wait_until* wait for *ivar* to be changed by a remote write or an atomic operation issued by a different PE. These routines can be used for point-to-point direct synchronization. A call to *shmem_wait* does not return until some other PE writes a value, not equal to *cmp_value*, into *ivar* on the waiting PE. A call to *shmem_wait_until* does not return until some other PE changes *ivar* to satisfy the condition implied by *cmp* and *cmp_value*. This mechanism is useful when a PE needs to tell another PE that it has completed some action. The *shmem_wait* routines return when *ivar* is no longer equal to *cmp_value*. The *shmem_wait_until* routines return when the compare condition is true. The compare condition is defined by the *ivar* argument compared with the *cmp_value* using the comparison operator, *cmp*.

If you are using *Fortran*, *ivar* must be a specific sized integer type according to the routine being called, as follows:

Routine	Data type
shmem_wait, shmem_wait_until	default INTEGER
shmem_int4_wait, shmem_int4_wait_until	INTEGER*4

shmem_int8_wait, shmem_int8_wait_until	INTEGER*8

The following *cmp* values are supported:

CMP Value	Comparison
C/C++:	
SHMEM_CMP_EQ	Equal
SHMEM_CMP_NE	Not equal
SHMEM_CMP_GT	Greater than
SHMEM_CMP_LE	Less than or equal to
SHMEM_CMP_LT	Less than
SHMEM_CMP_GE	Greater than or equal to
Fortran:	
SHMEM_CMP_EQ	Equal
SHMEM_CMP_NE	Not equal
SHMEM_CMP_GT	Greater than
SHMEM_CMP_LE	Less than or equal to
SHMEM_CMP_LT	Less than
SHMEM_CMP_GE	Greater than or equal to

Return Values

None.

Notes

None.

Note to implementors

Implementations must ensure that *shmem_wait* and *shmem_wait_until* do not return before the update of the memory indicated by *ivar* is fully complete. Partial updates to the memory must not cause *shmem_wait* or *shmem_wait_until* to return.

EXAMPLES

The following call returns when variable ivar is not equal to 100:

```
INCLUDE "shmem.fh"

INTEGER*8 IVAR
CALL SHMEM_INT8_WAIT(IVAR, INTEGER*8(100))
```

The following call to *SHMEM_INT8_WAIT_UNTIL* is equivalent to the call to *SHMEM_INT8_WAIT* in example 1:

```
INCLUDE "shmem.fh"

INTEGER*8 IVAR
CALL SHMEM_INT8_WAIT_UNTIL(IVAR, SHMEM_CMP_NE, INTEGER*8(100))
```

The following *C/C++* call waits until the sign bit in ivar is set by a transfer from a remote PE:

```
#include <stdio.h>
#include <shmem.h>

int ivar;
shmem_int_wait_until(&ivar, SHMEM_CMP_LT, 0);
```

The following *Fortran* example is in the context of a subroutine:

```
INCLUDE "shmem.fh"

SUBROUTINE EXAMPLE()
INTEGER FLAG_VAR
COMMON/FLAG/FLAG_VAR
. . .
FLAG_VAR = FLAG_VALUE    !  initialize the event variable
. . .
IF (FLAG_VAR .EQ.  FLAG_VALUE) THEN
        CALL SHMEM_WAIT(FLAG_VAR, FLAG_VALUE)
ENDIF
FLAG_VAR = FLAG_VALUE    !  reset the event variable for next time
. . .
END
```

8.8 Memory Ordering Routines

The following section discusses OpenSHMEM APIs that provide mechanisms to ensure ordering and/or delivery of *Put*, AMO, and memory store routines to symmetric data objects.

8.8.1 SHMEM_FENCE

Assures ordering of delivery of *Put*, AMOs, and memory store routines to symmetric data objects.

SYNOPSIS

C/C++:

```
void shmem_fence(void);
```

FORTRAN:

```
CALL SHMEM_FENCE
```

DESCRIPTION

Arguments

None.

API description

This routine assures ordering of delivery of *Put*, AMOs, and memory store routines to symmetric data objects. All *Put*, AMOs, and memory store routines to symmetric data objects issued to a particular remote PE prior to the call to *shmem_fence* are guaranteed to be delivered before any subsequent *Put*, AMOs, and memory store routines to symmetric data objects to the same PE. *shmem_fence* guarantees order of delivery, not completion.

Return Values

None.

Notes

shmem_fence only provides per-PE ordering guarantees and does not guarantee completion of delivery. There is a subtle difference between *shmem_fence* and *shmem_quiet*, in that, *shmem_quiet* guarantees completion of *Put*, AMOs, and memory store routines to symmetric data objects which makes the updates visible to all other PEs.

The *shmem_quiet* routine should be called if completion of PUT, AMOs, and memory store routines to symmetric data objects is desired when multiple remote PEs are involved.

EXAMPLES

The following *shmem_fence* example is for *C/C++* programs:

```
#include <stdio.h>
#include <shmem.h>

long dest[10] = {0};
int targ = 0;

int main(void)
{
  long source[10] = { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };
  int src = 99;
  shmem_init();
  if (shmem_my_pe() == 0) {
    shmem_long_put(dest, source, 10, 1);  /*put1*/
    shmem_long_put(dest, source, 10, 2);  /*put2*/
    shmem_fence();
    shmem_int_put(&targ, &src, 1, 1);  /*put3*/
    shmem_int_put(&targ, &src, 1, 2);  /*put4*/
  }
  shmem_barrier_all();  /* sync sender and receiver */
  printf("dest[0] on PE %d is %ld\n", shmem_my_pe(), dest[0]);
  return 1;
}
```

Put1 will be ordered to be delivered before *put3* and *put2* will be ordered to be delivered before *put4*.

8.8.2 SHMEM_QUIET

Waits for completion of all outstanding *Put*, AMOs, memory store, and non-blocking *Put* and *Get* routines to symmetric data objects issued by a PE.

SYNOPSIS

C/C++:

```
void shmem_quiet(void);
```

FORTRAN:

```
CALL SHMEM_QUIET
```

DESCRIPTION

Arguments

None.

API description

The *shmem_quiet* routine ensures completion of *Put*, AMOs, memory store, and non-blocking *Put* and

Get routines on symmetric data objects issued by the calling PE. All *Put*, AMOs, memory store, and non-blocking *Put* and *Get* routines to symmetric data objects are guaranteed to be completed and visible to all PEs when *shmem_quiet* returns.

Return Values

None.

Notes

shmem_quiet is most useful as a way of ensuring completion of several *Put*, AMOs, memory store, and non-blocking *Put* and *Get* routines to symmetric data objects initiated by the calling PE. For example, you might use *shmem_quiet* to await delivery of a block of data before issuing another *Put* or non-blocking *Put* routine, which sets a completion flag on another PE. *shmem_quiet* is not usually needed if *shmem_barrier_all* or *shmem_barrier* are called. The barrier routines wait for the completion of outstanding writes (*Put*, AMO, memory stores, and nonblocking *Put* and *Get* routines) to symmetric data objects on all PEs.

EXAMPLES

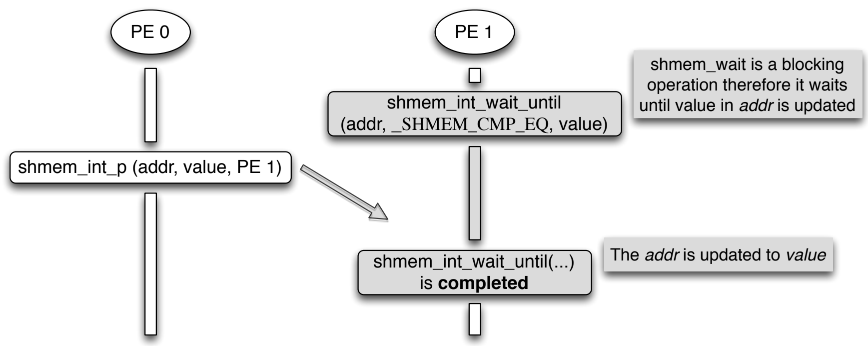
The following example uses *shmem_quiet* in a *C/C++* program:

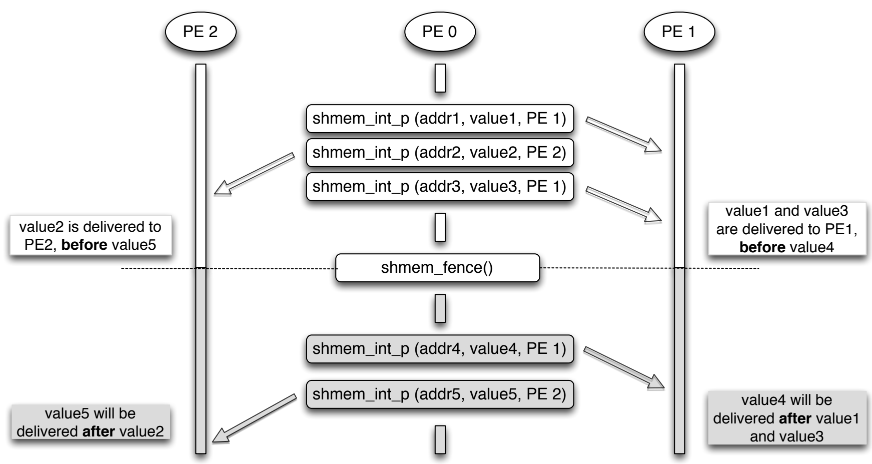
```
#include <stdio.h>
#include <shmem.h>

long dest[3] = {0};
int targ = 0;
long source[3] = {1, 2, 3};
int src = 90;

int main(void)
{
  long x[3] = {0};
  int y = 0;

  shmem_init();
  if (shmem_my_pe() == 0) {
    shmem_long_put(dest, source, 3, 1);  /*put1*/
    shmem_int_put(&targ, &src, 1, 2);  /*put2*/

    shmem_quiet();

    shmem_long_get(x, dest, 3, 1);    /*gets updated value from dest on PE 1 to local array x
     */
    shmem_int_get(&y, &targ, 1, 2);     /*gets updated value from targ on PE 2 to local
    variable y*/
    printf("x: {%ld,%ld,%ld}\n",x[0],x[1],x[2]); /*x: {1,2,3}*/
    printf("y: %d\n", y); /*y: 90*/

    shmem_int_put(&targ, &src, 1, 1);  /*put3*/
    shmem_int_put(&targ, &src, 1, 2);  /*put4*/
  }
  shmem_barrier_all();  /* sync sender and receiver */
  return 0;
}
```

Put1 and *put2* will be completed and visible before *put3* and *put4*.

8.8.3 Synchronization and Communication Ordering in OpenSHMEM

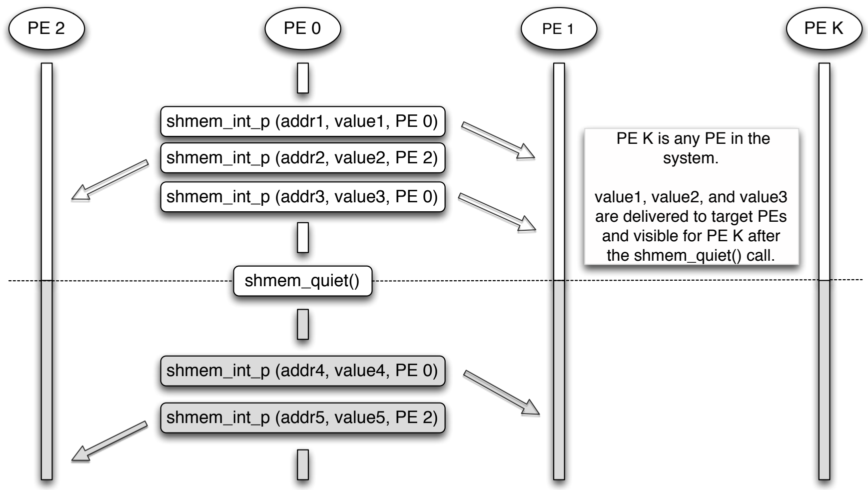
When using the OpenSHMEM API, synchronization, ordering, and completion of communication become critical. The updates via *Put* routines, AMOs and store routines on symmetric data cannot be guaranteed until some form of synchronization or ordering is introduced by the program user. The table below gives the different synchronization and ordering choices, and the situations where they may be useful.

<table>
<tr><th>OpenSHMEM API</th><th>Working of OpenSHMEM API</th></tr>
<tr><td>Point-to-point synchronization
shmem_wait,
shmem_wait_until</td><td>


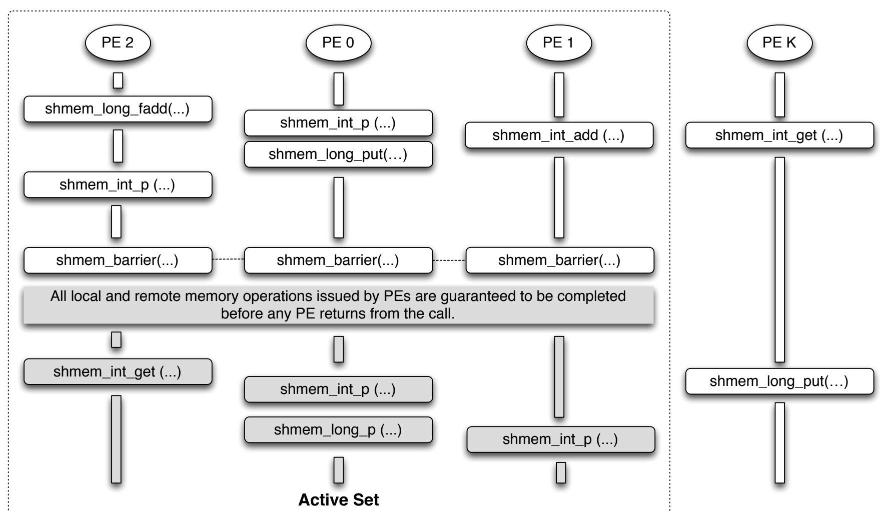
Waits for a symmetric variable to be updated by a remote PE. Should be used when computation on the local PE cannot proceed without the value that the remote PE is to update.</td></tr>
<tr><td>Ordering puts issued by a local PE
shmem_fence</td><td>


All Put routines, AMOs and store routines on symmetric data issued to same PE are guaranteed to be delivered before Puts (to the same PE) issued after the fence call.</td></tr>
</table>

<table>
<tr><th>OpenSHMEM API</th><th>Working of OpenSHMEM API</th></tr>
<tr><td>Ordering puts issued by all PE
shmem_quiet</td><td>

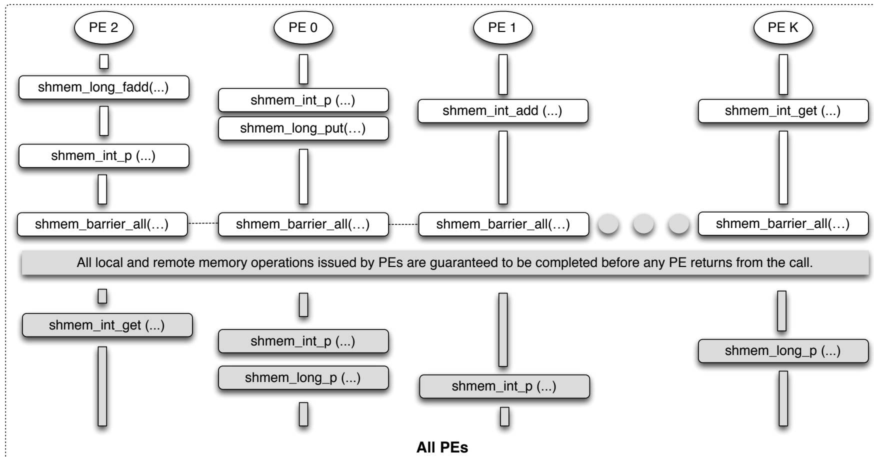


All Put routines, AMOs and store routines on symmetric data issued by a local PE to all remote PEs are guaranteed to be completed and visible once quiet returns. This routine should be used when all remote writes issued by a local PE need to be visible to all other PEs before the local PE proceeds.</td></tr>
<tr><td>Collective synchronization over an Active set
shmem_barrier</td><td>



All local and remote memory operations issued by all PEs within the Active set are guaranteed to be completed before any PE in the Active set returns from the call. Additionally, no PE my return from the barrier until all PEs in the Active set have entered the same barrier call. This routine should be used when synchronization as well as completion of all stores and remote memory updates via OpenSHMEM is required over a sub set of the executing PEs.</td></tr>
</table>

<table>
<tr><th>OpenSHMEM API</th><th>Working of OpenSHMEM API</th></tr>
<tr><td>Collective synchronization over all PEs
shmem_barrier_all</td><td>



All local and remote memory operations issued by all PEs are guaranteed to be completed before any PE returns from the call. Additionally no PE shall return from the barrier until all PEs have entered the same *shmem_barrier_all* call. This routine should be used when synchronization as well as completion of all stores and remote memory updates via OpenSHMEM is required over all PEs.</td></tr>
</table>

8.9 Distributed Locking Routines

The following section discusses OpenSHMEM locks as a mechanism to provide mutual exclusion. Three routines are available for distributed locking, *set, test* and *clear*.

8.9.1 SHMEM_LOCK

Releases, locks, and tests a mutual exclusion memory lock.

SYNOPSIS

C/C++:

```
void shmem_clear_lock(volatile long *lock);
void shmem_set_lock(volatile long *lock);
int shmem_test_lock(volatile long *lock);
```

FORTRAN:

```
INTEGER lock, SHMEM_TEST_LOCK
CALL SHMEM_CLEAR_LOCK(lock)
CALL SHMEM_SET_LOCK(lock)
I = SHMEM_TEST_LOCK(lock)
```

DESCRIPTION

Arguments

IN	*lock*	A symmetric data object that is a scalar variable or an array of length *1*. This data object must be set to *0* on all PEs prior to the first use. *lock* must be of type *long*. If you are using *Fortran*, it must be of default kind.

API description

The *shmem_set_lock* routine sets a mutual exclusion lock after waiting for the lock to be freed by any other PE currently holding the lock. Waiting PEs are assured of getting the lock in a first-come, first-served manner. The *shmem_clear_lock* routine releases a lock previously set by *shmem_set_lock* after ensuring that all local and remote stores initiated in the critical region are complete. The *shmem_test_lock* routine sets a mutual exclusion lock only if it is currently cleared. By using this routine, a PE can avoid blocking on a set lock. If the lock is currently set, the routine returns without waiting. These routines are appropriate for protecting a critical region from simultaneous update by multiple PEs.

Return Values

The *shmem_test_lock* routine returns *0* if the lock was originally cleared and this call was able to set the lock. A value of *1* is returned if the lock had been set and the call returned without waiting to set the lock.

Notes

The term symmetric data object is defined in Section 3. The lock variable should always be initialized to zero and accessed only by the OpenSHMEM locking API. Changing the value of the lock variable by other means without using the OpenSHMEM API, can lead to undefined behavior.

EXAMPLES

The following example uses *shmem_lock* in a *C* program.

```
#include <stdio.h>
#include <unistd.h>
#include <shmem.h>
long L = 0;

int main(int argc, char **argv)
{
   int me, slp;
   shmem_init();
   me = shmem_my_pe();
   slp = 1;
   shmem_barrier_all();
   if (me == 1)
      sleep (3);
   shmem_set_lock(&L);
   printf("%d: sleeping %d second%s...\n", me, slp, slp == 1 ? "" : "s");
   sleep(slp);
   printf("%d: sleeping...done\n", me);
   shmem_clear_lock(&L);
   shmem_barrier_all();
   return 0;
}
```

8.10 Cache Management

All of these routines are deprecated and are provided for backwards compatibility. Implementations must include all items in this section, and the routines should function properly and may notify the user about deprecation of their use.

8.10.1 SHMEM_CACHE

Controls data cache utilities.

SYNOPSIS

C/C++:

```
void shmem_clear_cache_inv(void);
void shmem_set_cache_inv(void);
void shmem_clear_cache_line_inv(void *dest);
void shmem_set_cache_line_inv(void *dest);
void shmem_udcflush(void);
void shmem_udcflush_line(void *dest);
```

FORTRAN:

```
CALL SHMEM_CLEAR_CACHE_INV
CALL SHMEM_SET_CACHE_INV
CALL SHMEM_SET_CACHE_LINE_INV(dest)
CALL SHMEM_UDCFLUSH
CALL SHMEM_UDCFLUSH_LINE(dest)
```

DESCRIPTION

Arguments

IN	*dest*	A data object that is local to the PE. *dest* can be of any noncharacter type. If you are using *Fortran*, it can be of any kind.

API description

shmem_set_cache_inv enables automatic cache coherency mode.

shmem_set_cache_line_inv enables automatic cache coherency mode for the cache line associated with the address of *dest* only.

shmem_clear_cache_inv disables automatic cache coherency mode previously enabled by *shmem_set_cache_inv* or *shmem_set_cache_line_inv*.

shmem_udcflush makes the entire user data cache coherent.

shmem_udcflush_line makes coherent the cache line that corresponds with the address specified by *dest*.

Return Values

None.

Notes

These routines have been retained for improved backward compatibility with legacy architectures. They are not required to be supported by implementing them as *no-ops* and where used, they may have no effect on cache line states.

EXAMPLES

None.

Annex A

Writing OpenSHMEM Programs

Incorporating OpenSHMEM into Programs

In this section, we describe how to write a "Hello World" OpenSHMEM program. To write a "Hello World" OpenSHMEM program we need to:

- Add the include file shmem.h (for *C*) or shmem.fh (for *Fortran*).
- Add the initialization call *shmem_init*, (line 9).
- Use OpenSHMEM calls to query the the total number of PEs (line 10) and PE id (line 11).
- There is no explicit finalize call; either a return from `main()` (line 13) or an explicit `exit()` acts as an implicit OpenSHMEM finalization.
- In OpenSHMEM the order in which lines appear in the output is not fixed as PEs execute asynchronously in parallel.

```
1  #include <stdio.h>
2  #include <shmem.h>          /* The shmem header file */
3
4  int
5  main (int argc, char *argv[])
6  {
7    int nprocs, me;
8
9    shmem_init ();
10   nprocs = shmem_n_pes ();
11   me = shmem_my_pe ();
12   printf ("Hello from %d of %d\n", me, nprocs);
13   return 0;
14 }
```

Listing A.1: Expected Output (4 processors)

```
Hello from 0 of 4
Hello from 2 of 4
Hello from 3 of 4
Hello from 1 of 4
```

OpenSHMEM also has a *Fortran* API, so for completeness we will now give the same program written in *Fortran*, in listing A:

```fortran
program hello

  include "shmem.fh"
  integer :: shmem_my_pe, shmem_n_pes

  integer :: npes, me

  call shmem_init ()
  npes = shmem_n_pes ()
  me = shmem_my_pe ()

  write (*, 1000) me, npes

 1000 format ('Hello from', 1X, I4, 1X, 'of', 1X, I4)

end program hello
```

Listing A.2: Expected Output (4 processors)

```
Hello from    0 of    4
Hello from    2 of    4
Hello from    3 of    4
Hello from    1 of    4
```

The following example shows a more complex OpenSHMEM program that illustrates the use of symmetric data objects. Note the declaration of the *static short dest* array and its use as the remote destination in OpenSHMEM short *Put*. The use of the *static* keyword results in the *dest* array being symmetric on PE *0* and PE *1*. Each PE is able to transfer data to the *dest* array by simply specifying the local address of the symmetric data object which is to receive the data. This aids programmability, as the address of the *dest* need not be exchanged with the active side (PE *0*) prior to the RMA (Remote Memory Access) routine. Conversely, the declaration of the *short source* array is asymmetric. Because the *Put* handles the references to the *source* array only on the active (local) side, the asymmetric *source* object is handled correctly.

```c
#include <stdio.h>
#include <shmem.h>
#define SIZE 16
int
main(int argc, char* argv[])
{
        short  source[SIZE];
        static short  dest[SIZE];
        int i, npes;
        shmem_init();
        npes = shmem_n_pes();
        if (shmem_my_pe() == 0) {
                /* initialize array */
                for(i = 0; i < SIZE; i++)
                        source[i] = i;
                /* local, not symmetric */
                /* static makes it symmetric */
                /* put "size" words into dest on each PE */
                for(i = 1; i < npes; i++)
                        shmem_short_put(dest, source, SIZE, i);
        }
        shmem_barrier_all(); /* sync sender and receiver */
        if (shmem_my_pe() != 0) {
                printf("dest on PE %d is \t", shmem_my_pe());
                for(i = 0; i < SIZE; i++)
                        printf("%hd \t", dest[i]);
                printf("\n");
        }
        shmem_finalize();
        return 0;
}
```

Listing A.3: Expected Output (4 processors)

```
dest on PE 1 is 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
dest on PE 2 is 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
dest on PE 3 is 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
```

Annex B

Compiling and Running Programs

As of this writing, the OpenSHMEM specification is silent regarding how OpenSHMEM programs are compiled, linked and run. This section shows some examples of how wrapper programs are utilized in the OpenSHMEM Reference Implementation to compile and launch programs.

1 Compilation

Programs written in *C*

The OpenSHMEM Reference Implementation provides a wrapper program named **oshcc**, to aid in the compilation of *C* programs, the wrapper could be called as follows:

```
oshcc <compiler options> -o myprogram myprogram.c
```

Where the ⟨compiler options⟩ are options understood by the underlying *C* compiler.

Programs written in *C++*

The OpenSHMEM Reference Implementation provides a wrapper program named **oshCC**, to aid in the compilation of *C++* programs, the wrapper could be called as follows:

```
oshCC <compiler options> -o myprogram myprogram.cpp
```

Where the ⟨compiler options⟩ are options understood by the underlying *C++* compiler called by **oshCC**.

Programs written in *Fortran*

The OpenSHMEM Reference Implementation provides a wrapper program named **oshfort**, to aid in the compilation of *Fortran* programs, the wrapper could be called as follows:

```
oshfort <compiler options> -o myprogram myprogram.f
```

Where the ⟨compiler options⟩ are options understood by the underlying *Fortran* compiler called by **oshfort**.

2 Running Programs

The OpenSHMEM Reference Implementation provides a wrapper program named **oshrun**, to launch OpenSHMEM programs, the wrapper could be called as follows:

```
oshrun <additional options> -np <#> <program> <program arguments>
```

The program arguments for **oshrun** are:

⟨additional options⟩	Options passed to the underlying launcher.
-np ⟨#⟩	The number of PEs to be used in the execution.
⟨program⟩	The program executable to be launched.
⟨program arguments⟩	Flags and other parameters to pass to the program.

Annex C

Undefined Behavior in OpenSHMEM

The specification provides guidelines to the expected behavior of various library routines. In cases where routines are improperly used or the input is not in accordance with the specification, undefined behavior may be observed. Depending on the implementation there are many interpretations of undefined behavior.

Inappropriate Usage	**Undefined Behavior**
Uninitialized library	If OpenSHMEM is not initialized through a call to *shmem_init*, subsequent accesses to OpenSHMEM routines have undefined results. An implementation may choose, for example, to try to continue or abort immediately upon the first call to an uninitialized routine.
Accessing non-existent PEs	If a communications routine accesses a non-existent PE, then the OpenSHMEM library can choose to handle this situation in an implementation-defined way. For example, the library may issue an error message saying that the PE accessed is outside the range of accessible PEs, or may exit without a warning.
Use of non-symmetric variables	Some routines require remotely accessible variables to perform their function. A *Put* to a non-symmetric variable can be trapped where possible and the library can abort the program. Another implementation may choose to continue either with a warning or silently.
Non-symmetric variables	The symmetric memory management routines are collectives, which means that all PEs in the program must issue the same *shmem_malloc* call with the same size request. Program behavior after a mismatched *shmem_malloc* call is undefined.
Use of NULL pointers with non-zero *len* specified	In any OpenSHMEM routine that takes a pointer and *len* describing the number of elements in that pointer, NULL may not be specified for the pointer unless the corresponding *len* is also specified as zero. Otherwise, the resulting behavior is undefined. The following cases summarize this behavior: • *len* is 0, pointer is NULL: supported. • *len* is not 0, pointer is NULL: undefined behavior. • *len* is 0, pointer is not NULL: supported. • *len* is not 0, pointer is not NULL: supported.
Multiple calls to *shmem_init*	In an OpenSHMEM program where *shmem_init* has already be called, any subsequent calls to *shmem_init* result in undefined behavior.

Annex D

Interoperability with other Programming Models

1 MPI Interoperability

OpenSHMEM routines can be used in conjunction with MPI routines in the same program. For example, on SGI systems, programs that use both MPI and OpenSHMEM routines call *MPI_Init* and *MPI_Finalize* but omit the call to the *shmem_init* routine. OpenSHMEM PE numbers are equal to the MPI rank within the *MPI_COMM_WORLD* environment variable. Note that this precludes use of OpenSHMEM routines between processes in different *MPI_COMM_WORLD*s. MPI processes started using the *MPI_Comm_spawn* routine, for example, cannot use OpenSHMEM routines to communicate with their parent MPI processes.

On SGI systems where MPI jobs use TCP/sockets for inter-host communication, OpenSHMEM routines can be used to communicate with processes running on the same host. The *shmem_pe_accessible* routine can be used to determine if a remote PE is accessible via OpenSHMEM communication from the local PE. When running an MPI program involving multiple executable files, OpenSHMEM routines can be used to communicate with processes running from the same or different executable files, provided that the communication is limited to symmetric data objects. On these systems, static memory such as a *Fortran* common block or *C* global variable, is symmetric between processes running from the same executable file, but is not symmetric between processes running from different executable files. Data allocated from the symmetric heap (*shmem_malloc* or *shpalloc*) is symmetric across the same or different executable files. The routine *shmem_addr_accessible* can be used to determine if a local address is accessible via OpenSHMEM communication from a remote PE.

Another important feature of these systems is that the *shmem_pe_accessible* routine returns *TRUE* only if the remote PE is a process running from the same executable file as the local PE, indicating that full OpenSHMEM support (static memory and symmetric heap) is available. When using OpenSHMEM routines within an MPI program, the use of MPI memory placement environment variables is required when using non-default memory placement options.

Annex E

History of OpenSHMEM

SHMEM has a long history as a parallel programming model, having been used extensively on a number of products since 1993, including Cray T3D, Cray X1E, the Cray XT3/4, SGI Origin, SGI Altix, clusters based on the Quadrics interconnect, and to a very limited extent, Infiniband based clusters.

- A SHMEM Timeline
  - Cray SHMEM
    - SHMEM first introduced by Cray Research Inc. in 1993 for Cray T3D
    - Cray is acquired by SGI in 1996
    - Cray is acquired by Tera in 2000 (MTA)
    - Platforms: Cray T3D, T3E, C90, J90, SV1, SV2, X1, X2, XE, XMT, XT
  - SGI SHMEM
    - SGI purchases Cray Research Inc. and SHMEM was integrated into SGI's Message Passing Toolkit (MPT)
    - SGI currently owns the rights to SHMEM and OpenSHMEM
    - Platforms: Origin, Altix 4700, Altix XE, ICE, UV
    - SGI was purchased by Rackable Systems in 2009
    - SGI and Open Source Software Solutions, Inc. (OSSS) signed a SHMEM trademark licensing agreement, in 2010
  - Other Implementations
    - Quadrics (Vega UK, Ltd.)
    - Hewlett Packard
    - GPSHMEM
    - IBM
    - QLogic
    - Mellanox
    - University of Florida
- OpenSHMEM Implementations
  - SGI OpenSHMEM
  - University of Houston - OpenSHMEM Reference Implementation
  - Mellanox ScalableSHMEM
  - Portals-SHMEM
  - IBM OpenSHMEM

Annex F

OpenSHMEM Specification and Deprecated API

For the OpenSHMEM Specification(s), deprecation is the process of identifying API that is supported but no longer recommended for use by program users. For OpenSHMEM library users, said API **must** be supported until clearly indicated as otherwise by the Specification. In this chapter we will record the API that has been deprecated, the OpenSHMEM Specification that effected the deprecation, and if the feature is supported in the current version of the specification.

Deprecated API	Deprecated Since	Currently Supported(?)	Replaced By
_my_pe	1.2	Yes	*shmem_my_pe*
_num_pes	1.2	Yes	*shmem_n_pes*
shmalloc	1.2	Yes	*shmem_malloc*
shfree	1.2	Yes	*shmem_free*
shrealloc	1.2	Yes	*shmem_realloc*
shmemalign	1.2	Yes	*shmem_align*
start_pes	1.2	Yes	*shmem_init*
SHMEM_PUT	1.2	Yes	*SHMEM_PUT8* or *SHMEM_PUT64*
SHMEM_CACHE	1.3	Yes	(none)
_SHMEM_* constants	1.3	Yes	(none)

Annex G

Changes to this Document

1 Version 1.3

This section summarizes the changes from the OpenSHMEM specification Version 1.2 to Version 1.3. Many major changes to the specification was introduced in Version 1.3. This includes non-blocking RMA operations, generic interfaces for various OpenSHMEM interfaces, atomic *Put* and *Get* operations, and Alltoall interfaces.

The following list describes the specific changes in 1.3:

- Clarified implementation of PEs as threads.
- Added **const** to every read-only pointer argument.
- Clarified definition of *Fence*.
  See Section 2.
- Clarified implementation of symmetric memory allocation.
  See Section 3.
- Restricted atomic operation guarantees to other atomic operations with the same datatype.
  See Section 4.2.
- Deprecation of all constants that start with *_SHMEM_**.
  See Section 6.
- Added a type-generic interface to OpenSHMEM RMA and AMO operations based on *C11* Generics.
  See Sections 8.3, 8.4 and 8.5.
- New non-blocking variants of remote memory access, *SHMEM_PUT_NBI* and *SHMEM_GET_NBI*.
  See Sections 8.4.1 and 8.4.2.
- New atomic elemental read and write operations, *SHMEM_FETCH* and *SHMEM_SET*.
  See Sections 8.5.7 and 8.5.8
- New alltoall data exchange operations, *SHMEM_ALLTOALL* and *SHMEM_ALLTOALLS*.
  See Sections 8.6.6 and 8.6.7.
- Added **volatile** to remotely accessible pointer argument in *SHMEM_WAIT* and *SHMEM_LOCK*.
  See Sections 8.7.1 and 8.9.1.
- Deprecation of *SHMEM_CACHE*.
  See Section 8.10.1.

2 Version 1.2

This section summarizes the changes from the OpenSHMEM specification Version 1.1 to Version 1.2. A major change in this version is that it improves upon the execution model described in 1.1 by introducing an explicit *shmem_finalize* library call. This provides a collective mechanism of exiting an OpenSHMEM program and releasing resources used by the library.

The following list describes the specific changes in 1.2:

- Added specification of *pSync* initialization for all routines that use it.
- Replaced all placeholder variable names *target* with *dest* to avoid confusion with Fortran 'target' keyword.
- New Execution Model for exiting/finishing OpenSHMEM programs.
  See Section 4.
- New library constants to support API that query version and name information.
  See Section 6.
- New API *shmem_init* to provide mechanism to start an OpenSHMEM program and replace deprecated *start_pes*.
  See Section 8.1.1.
- Deprecation of *_my_pe* and *_num_pes* routines.
  See Sections 8.1.2 and 8.1.3.
- New API *shmem_finalize* to provide collective mechanism to cleanly exit an OpenSHMEM program and release resources.
  See Section 8.1.4.
- New API *shmem_global_exit* to provide mechanism to exit an OpenSHMEM program.
  See Section 8.1.5.
- Clarification related to the address of the referenced object in *shmem_ptr*.
  See Section 8.1.8.
- New API to query the version and name information.
  See Section 8.1.9 and 8.1.10.
- OpenSHMEM library API normalization. All C symmetric memory management API begins with *shmem_*.
  See Section 8.2.1.
- Notes and clarifications added to *shmem_malloc*.
  See Section 8.2.1.
- Deprecation of Fortran API routine *SHMEM_PUT*.
  See Section 8.3.1.
- Clarification related to *shmem_wait*.
  See Section 8.7.1.
- Undefined behavior for null pointers without zero counts added.
  See Annex C
- Addition of new Annex for clearly specifying deprecated API and its support in the existing specification version.
  See Annex F.

3 Version 1.1

This section summarizes the changes from the OpenSHMEM specification Version 1.0 to the Version 1.1. A major change in this version is that it provides an accurate description of OpenSHMEM interfaces so that they are in agreement with the SGI specification. This version also explains OpenSHMEM 's programming, memory, and execution model. The document was thoroughly changed to improve the readability of specification and usability of interfaces. The code examples were added to demonstrate the usability of API. Additionally, diagrams were added to help understand the subtle semantic differences of various operations.

The following list describes the specific changes in 1.1:

- Clarifications of the completion semantics of memory synchronization interfaces.
  See Section 8.8.
- Clarification of the completion semantics of memory load and store operations in context of *shmem_barrier_all* and *shmem_barrier* routines.
  See Section 8.6.1 and 8.6.2.
- Clarification of the completion and ordering semantics of *shmem_quiet* and *shmem_fence*.
  See Section 8.8.2 and 8.8.1.
- Clarifications of the completion semantics of RMA and AMO routines.
  See Sections 8.3 and 8.5
- Clarifications of the memory model and the memory alignment requirements for symmetric data objects.
  See Section 3.
- Clarification of the execution model and the definition of a PE.
  See Section 4
- Clarifications of the semantics of *shmem_pe_accessible* and *shmem_addr_accessible*.
  See Section 8.1.6 and 8.1.7.
- Added an annex on interoperability with MPI.
  See Annex D.
- Added examples to the different interfaces.
- Clarification of the naming conventions for constant in *C* and *Fortran*.
  See Section 6 and 8.7.1.
- Added API calls: *shmem_char_p*, *shmem_char_g*.
  See Sections 8.3.2 and 8.3.5.
- Removed API calls: *shmem_char_put*, *shmem_char_get*.
  See Sections 8.3.1 and 8.3.4.
- The usage of *ptrdiff_t*, *size_t*, and *int* in the interface signature was made consistent with the description.
  See Sections 8.6, 8.3.3, and 8.3.6.
- Revised *shmem_barrier* example.
  See Section 8.6.2.
- Clarification of the initial value of *pSync* work arrays for *shmem_barrier*.
  See Section 8.6.2.
- Clarification of the expected behavior when multiple *start_pes* calls are encountered has been clarified.
  See Section 8.1.11.
- Corrected the definition of atomic increment operation.
  See Section 8.5.5.

- Clarification of the size of the symmetric heap and when it is set.
  See Section 8.2.1.

- Clarification of the integer and real sizes for *Fortran* API.
  See Sections 8.5.1, 8.5.2, 8.5.3, 8.5.4, 8.5.5, and 8.5.6.

- Clarification of the expected behavior on program *exit*.
  See Section 4, Execution Model.

- More detailed description for the progress of OpenSHMEM operations provided.
  See Section 4.1.

- Clarification of naming convention for non-standard interfaces and their inclusion in *shmemx.h*.
  See Section 5.

- Various fixes to OpenSHMEM code examples across the specification to include appropriate header files.

- Removing requirement that implementations should detect size mismatch and return error information for *shmalloc* and ensuring consistent language.
  See Sections 8.2.1 and Annex C.

- Fortran programming fixes for examples.
  See Sections 8.6.5 and 8.7.1.

- Clarifications of the reuse *pSync* and *pWork* across collectives.
  See Sections 8.6, 8.6.3, 8.6.4 and 8.6.5.

- Name changes for UV and ICE for SGI systems.
  See Annex E.