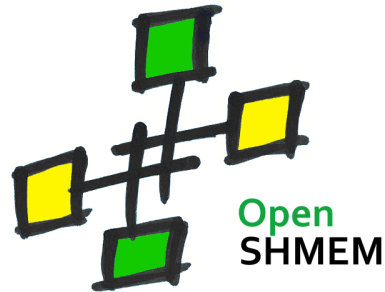# OpenSHMEM

Application Programming Interface

<http://www.openshmem.org/>

Version 1.5

13th June 2019

Development by

- For a current list of contributors and collaborators please see
  <http://www.openshmem.org/site/Contributors/>

- For a current list of OpenSHMEM implementations and tools, please see
  <http://openshmem.org/site/Links#impl/>

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Acknowledgments

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 Open-SHMEM library calls. Through the different versions, OpenSHMEM will continue to address the requirements of the PGAS community. As of this specification, many existing vendors support 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 Open-SHMEM section.

The OpenSHMEM[1] effort is driven by the DoD with continuous input from the OpenSHMEM community. To see all of the contributors and participants for the OpenSHMEM API, please see: `http://www.openshmem.org/site/Contributors`. In addition to the specification, the effort includes 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 only 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*[2]. The *C++* interface is currently the same as that for *C*. Unlike Unified Parallel C, *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, where the PEs are either single or multithreaded.

    (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 HPE.
[2] As of OpenSHMEM 1.4, the *Fortran* interface has been deprecated.

(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. **Communication Management**

(a) *Contexts*: Contexts are containers for communication operations. Each context provides an environment where the operations performed on that context are ordered and completed independently of other operations performed by the application.

4. **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.

5. **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) *Bitwise Operations*: The PE initiating the bitwise operation specifies the operand value to the bitwise operation to be performed on the symmetric data object on the remote PE.

(e) *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.

(f) *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.

(g) *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.

(h) *Fetch and Bitwise Operations*: The PE initiating the bitwise operation specifies the operand value to the bitwise operation to be performed on the symmetric data object on the remote PE and returns the old value.

6. **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 remote 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.

7. **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.

(d) *All-to-All*: All PEs participating in the routine exchange a fixed amount of contiguous or strided data with all other PEs in the active set.

8. **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.

— deprecation start ——————————————————————————————

9. **Data Cache Control**

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

——————————————————————————————— deprecation end —

3 Memory Model
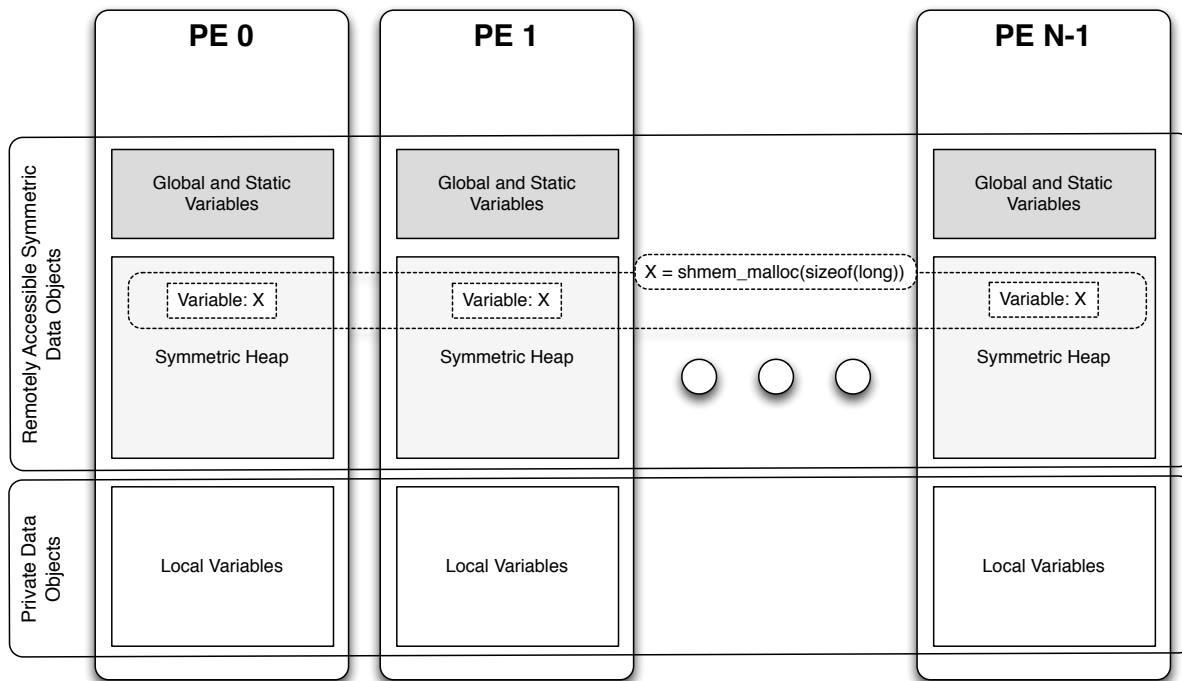
Figure 1: OpenSHMEM Memory Model

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[3]. (For the definition of what is accessible, see the descriptions for *shmem_pe_accessible*

---

[3]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 10.3.1

and *shmem_addr_accessible* in sections 10.1.6 and 10.1.7.) Symmetric data objects accessed via typed and type-generic OpenSHMEM interfaces are required to be naturally aligned based on their type requirements and underlying architecture. In OpenSHMEM the following kinds of data objects are symmetric:

- ——— deprecation start ———————————————————————————————————————
  Fortran data objects in common blocks or with the *SAVE* attribute. These data objects must not be defined in a dynamic shared object (DSO).
  —— deprecation end ———

- Global and static *C* and *C++* variables. These data objects must not be defined in a DSO.

- ——— deprecation start ———————————————————————————————————————
  Fortran arrays allocated with *shpalloc*
  —— deprecation end ———

- *C* and *C++* data allocated by OpenSHMEM memory management routines (Section 10.3)

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.

3.1 Atomicity Guarantees

OpenSHMEM contains a number of routines that perform atomic operations on symmetric data objects, which are defined in Section 10.8. The atomic routines guarantee that concurrent accesses by any of these routines to the same location and using the same datatype (specified in Tables 4 and 5) will be exclusive. OpenSHMEM atomic operations do not guarantee exclusivity in the following scenarios, all of which result in undefined behavior.

1. When concurrent accesses to the same location are performed using OpenSHMEM atomic operations using different datatypes.

2. When atomic and non-atomic OpenSHMEM operations are used to access the same location concurrently.

3. When OpenSHMEM atomic operations and non-OpenSHMEM operations (e.g. load and store operations) are used to access the same location concurrently.

For example, during the execution of an atomic remote integer increment, i.e. *shmem_atomic_inc*, 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.

The following *C/C++* example illustrates scenario 1. In this example, different datatypes are used to access the same location concurrently, resulting in undefined behavior. The undefined behavior can be resolved by using the same datatype in all concurrent operations. For example, the 32-bit value can be left-shifted and a 64-bit atomic OR operation can be used.

```
#include <shmem.h>

int main(void) {
    static uint64_t x = 0;

    shmem_init();
    /* Undefined behavior: The following AMOs access the same location concurrently using
     * different types. */
    if (shmem_my_pe() > 0)
```

```
    shmem_uint32_atomic_or((uint32_t*)&x, shmem_my_pe()+1, 0);       1
  else                                                               2
    shmem_uint64_atomic_or(&x, shmem_my_pe()+1, 0);                  3
                                                                     4
  shmem_finalize();                                                  5
  return 0;                                                          6
}                                                                    7
```

The following *C/C++* example illustrates scenario 2. In this example, atomic increment operations are concurrent with a non-atomic reduction operation, resulting in undefined behavior. The undefined behavior can be resolved by inserting a barrier operation before the reduction. The barrier ensures that all local and remote AMOs have completed before the reduction operation accesses *x*.

```
#include <shmem.h>

int main(void) {
    static long psync[SHMEM_REDUCE_SYNC_SIZE];
    static int pwrk[SHMEM_REDUCE_MIN_WRKDATA_SIZE];
    static int x = 0, y = 0;

    for (int i = 0; i < SHMEM_REDUCE_SYNC_SIZE; i++)
        psync[i] = SHMEM_SYNC_VALUE;

    shmem_init();
    shmem_int_atomic_inc(&x, (shmem_my_pe()+1) % shmem_n_pes());
    /* Undefined behavior: The following reduction operation performs accesses to symmetric
     * variable 'x' that are concurrent with previously issued atomic increment operations
     * on the same variable. */
    shmem_int_sum_to_all(&y, &x, 1, 0, 0, shmem_n_pes(), pwrk, psync);

    shmem_finalize();
    return 0;
}
```

The following *C/C++* example illustrates scenario 3. In this example, an OpenSHMEM atomic increment operation is concurrent with a local increment operation, resulting in undefined behavior. The undefined behavior can be resolved by replacing the local increment operation with an OpenSHMEM atomic increment.

```
#include <shmem.h>

int main(void) {
    static int x = 0;

    shmem_init();
    /* Undefined behavior: OpenSHMEM atomic increment operations are concurrent with the local
     * increment of symmetric variable 'x'. */
    if (shmem_my_pe() > 0)
        shmem_int_atomic_inc(&x, 0);
    else
        x++;

    shmem_finalize();
    return 0;
}
```

4 Execution Model

An OpenSHMEM program consists of a set of OpenSHMEM processes called PEs that execute in an 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 may be either single or multithreaded. 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*[4] or *shmem_init_thread* before using any of the other OpenSHMEM library routines. An Open-

---
[4]*start_pes* has been deprecated as of OpenSHMEM 1.2

SHMEM program concludes its use of the OpenSHMEM library when all PEs call *shmem_finalize* or any PE calls *shmem_global_exit*. During a call to *shmem_finalize*, the OpenSHMEM library must complete all pending communication and release all the resources associated to the library using an implicit collective synchronization across PEs. 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 one less than the total number of PEs. 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*, *atomic*, etc) and complete communication operations with that computationally-bound PE without that PE issuing any explicit OpenSHMEM calls. One-sided 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.

5   Language Bindings and Conformance

OpenSHMEM provides ISO *C* and *Fortran 90* language bindings. As of OpenSHMEM 1.4, the *Fortran* API is deprecated. For rationale and considerations of future *Fortran* use of OpenSHMEM, see Section 2.13.

Any implementation that provides both *C* and *Fortran* bindings can claim conformance to the specification. Alternatively, an implementation may claim conformance only with respect to one of those languages. For example, an implementation that provides 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 *shmem.h* for *C* and *shmem.fh* for *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* and *shmemx.fh* include files for *C* and *Fortran* language bindings, respectively. These header files must exist, even if no extensions are provided. Any extensions shall use the *shmemx_* prefix for all routine, variable, and constant names.

6   Library Constants

The OpenSHMEM library provides a set of compile-time constants that may be used to specify options to API routines, provide implementation-specific parameters, or return information about the implementation. All constants that start with _*SHMEM_** are deprecated, but provided for backwards compatibility.

Constant	Description
C/C++: *SHMEM_THREAD_SINGLE*	The OpenSHMEM thread support level which specifies that the program must not be multithreaded. See Section 10.2 for more detail about its use.
C/C++: *SHMEM_THREAD_FUNNELED*	The OpenSHMEM thread support level which specifies that the program may be multithreaded but must ensure that only the main thread invokes the OpenSHMEM interfaces. See Section 10.2 for more detail about its use.
C/C++: *SHMEM_THREAD_SERIALIZED*	The OpenSHMEM thread support level which specifies that the program may be multithreaded but must ensure that the OpenSHMEM interfaces are not invoked concurrently by multiple threads. See Section 10.2 for more detail about its use.
C/C++: *SHMEM_THREAD_MULTIPLE*	The OpenSHMEM thread support level which specifies that the program may be multithreaded and any thread may invoke the OpenSHMEM interfaces. See Section 10.2 for more detail about its use.
C/C++: *SHMEM_TEAM_NUM_CONTEXTS*	The bitwise flag which specifies that a team creation routine should use the *num_contexts* member of the provided *shmem_team_config_t* configuration parameter as a request. See Sections 10.4.3 and 10.4.6 for more detail about its use.
C/C++: *SHMEM_TEAM_INVALID*	A value corresponding to an invalid team. This value can be used to initialize or update team handles to indicate that they do not reference a valid team. When managed in this way, applications can use an equality comparison to test whether a given team handle references a valid team. See Section 10.4 for more detail about its use.
C/C++: *SHMEM_CTX_INVALID*	A value corresponding to an invalid communication context. This value can be used to initialize or update context handles to indicate that they do not reference a valid context. When managed in this way, applications can use an equality comparison to test whether a given context handle references a valid context. See Section 10.5 for more detail about its use.
C/C++: *SHMEM_CTX_SERIALIZED*	The context creation option which specifies that the given context is shareable but will not be used by multiple threads concurrently. See Section 10.5.1 for more detail about its use.
C/C++: *SHMEM_CTX_PRIVATE*	The context creation option which specifies that the given context will be used only by the thread that created it. See Section 10.5.1 for more detail about its use.
C/C++: *SHMEM_CTX_NOSTORE*	The context creation option which specifies that quiet and fence operations performed on the given context are not required to enforce completion and ordering of memory store operations. See Section 10.5.1 for more detail about its use.

Constant	Description

C/C++:
    SHMEM_SYNC_VALUE
 	
— deprecation start —————————————————
 	
C/C++:
    _SHMEM_SYNC_VALUE
 	
Fortran:
    SHMEM_SYNC_VALUE
 	
————————————————— deprecation end —
	The value used to initialize the elements of *pSync* arrays. The value of this constant is implementation specific. See Section 10.9 for more detail about its use.

C/C++:
    SHMEM_SYNC_SIZE
 	
— deprecation start —————————————————
 	
Fortran:
    SHMEM_SYNC_SIZE
 	
————————————————— deprecation end —
	Length of a work array that can be used with any SHMEM collective communication operation. Work arrays sized for specific operations may consume less memory. The value of this constant is implementation specific. See Section 10.9 for more detail about its use.

C/C++:
    SHMEM_BCAST_SYNC_SIZE
 	
— deprecation start —————————————————
 	
C/C++:
    _SHMEM_BCAST_SYNC_SIZE
 	
Fortran:
    SHMEM_BCAST_SYNC_SIZE
 	
————————————————— deprecation end —
	Length of the *pSync* arrays needed for broadcast routines. The value of this constant is implementation specific. See Section 10.9.5 for more detail about its use.

C/C++:
    SHMEM_REDUCE_SYNC_SIZE
 	
— deprecation start —————————————————
 	
C/C++:
    _SHMEM_REDUCE_SYNC_SIZE
 	
Fortran:
    SHMEM_REDUCE_SYNC_SIZE
 	
————————————————— deprecation end —
	Length of the work arrays needed for reduction routines. The value of this constant is implementation specific. See Section 10.9.7 for more detail about its use.

Constant	Description

C/C++:
    SHMEM_BARRIER_SYNC_SIZE
 	
— deprecation start ————————————
 	
C/C++:
    _SHMEM_BARRIER_SYNC_SIZE
 	
Fortran:
    SHMEM_BARRIER_SYNC_SIZE
 	
———————————— deprecation end —
	Length of the work array needed for barrier routines. The value of this constant is implementation specific. See Section 10.9.2 for more detail about its use.

C/C++:
    SHMEM_COLLECT_SYNC_SIZE
 	
— deprecation start ————————————
 	
C/C++:
    _SHMEM_COLLECT_SYNC_SIZE
 	
Fortran:
    SHMEM_COLLECT_SYNC_SIZE
 	
———————————— deprecation end —
	Length of the work array needed for collect routines. The value of this constant is implementation specific. See Section 10.9.6 for more detail about its use.

C/C++:
    SHMEM_ALLTOALL_SYNC_SIZE
 	
— deprecation start ————————————
 	
Fortran:
    SHMEM_ALLTOALL_SYNC_SIZE
 	
———————————— deprecation end —
	Length of the work array needed for *shmem_alltoall* routines. The value of this constant is implementation specific. See Section 10.9.8 for more detail about its use.

C/C++:
    SHMEM_ALLTOALLS_SYNC_SIZE
 	
— deprecation start ————————————
 	
Fortran:
    SHMEM_ALLTOALLS_SYNC_SIZE
 	
———————————— deprecation end —
	Length of the work array needed for *shmem_alltoalls* routines. The value of this constant is implementation specific. See Section 10.9.9 for more detail about its use.

Constant	Description

C/C++:
    SHMEM_REDUCE_MIN_WRKDATA_SIZE
 	
— deprecation start —————————————————
 	
C/C++:
    _SHMEM_REDUCE_MIN_WRKDATA_SIZE
 	
Fortran:
    SHMEM_REDUCE_MIN_WRKDATA_SIZE
 	
————————————————— deprecation end —
	Minimum length of work arrays used in various collective routines.

C/C++:
    SHMEM_MAJOR_VERSION
 	
— deprecation start —————————————————
 	
C/C++:
    _SHMEM_MAJOR_VERSION
 	
Fortran:
    SHMEM_MAJOR_VERSION
 	
————————————————— deprecation end —
	Integer representing the major version of OpenSHMEM Specification in use.

C/C++:
    SHMEM_MINOR_VERSION
 	
— deprecation start —————————————————
 	
C/C++:
    _SHMEM_MINOR_VERSION
 	
Fortran:
    SHMEM_MINOR_VERSION
 	
————————————————— deprecation end —
	Integer representing the minor version of OpenSHMEM Specification in use.

C/C++:
    SHMEM_MAX_NAME_LEN
 	
— deprecation start —————————————————
 	
C/C++:
    _SHMEM_MAX_NAME_LEN
 	
Fortran:
    SHMEM_MAX_NAME_LEN
 	
————————————————— deprecation end —
	Integer representing the maximum length of *SHMEM_VENDOR_STRING*.

Constant	Description

C/C++:
    SHMEM_VENDOR_STRING
 	
— deprecation start ————————————
 	
C/C++:
    _SHMEM_VENDOR_STRING
 	
Fortran:
    SHMEM_VENDOR_STRING
 	
———————————— deprecation end —
	String representing vendor defined information of size at most *SHMEM_MAX_NAME_LEN*. In *C/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*.

C/C++:
    SHMEM_CMP_EQ
 	
— deprecation start ————————————
 	
C/C++:
    _SHMEM_CMP_EQ
 	
Fortran:
    SHMEM_CMP_EQ
 	
———————————— deprecation end —
	An integer constant expression corresponding to the "equal to" comparison operation. See Section 10.10 for more detail about its use.

C/C++:
    SHMEM_CMP_NE
 	
— deprecation start ————————————
 	
C/C++:
    _SHMEM_CMP_NE
 	
Fortran:
    SHMEM_CMP_NE
 	
———————————— deprecation end —
	An integer constant expression corresponding to the "not equal to" comparison operation. See Section 10.10 for more detail about its use.

C/C++:
    SHMEM_CMP_LT
 	
— deprecation start ————————————
 	
C/C++:
    _SHMEM_CMP_LT
 	
Fortran:
    SHMEM_CMP_LT
 	
———————————— deprecation end —
	An integer constant expression corresponding to the "less than" comparison operation. See Section 10.10 for more detail about its use.

Constant	Description

C/C++:
    SHMEM_CMP_LE
 	
— deprecation start ——————————————
 	
C/C++:
    _SHMEM_CMP_LE
 	
Fortran:
    SHMEM_CMP_LE
 	
————————————————— deprecation end —
	An integer constant expression corresponding to the "less than or equal to" comparison operation. See Section 10.10 for more detail about its use.

C/C++:
    SHMEM_CMP_GT
 	
— deprecation start ——————————————
 	
C/C++:
    _SHMEM_CMP_GT
 	
Fortran:
    SHMEM_CMP_GT
 	
———————————————— deprecation end —
	An integer constant expression corresponding to the "greater than" comparison operation. See Section 10.10 for more detail about its use.

C/C++:
    SHMEM_CMP_GE
 	
— deprecation start ——————————————
 	
C/C++:
    _SHMEM_CMP_GE
 	
Fortran:
    SHMEM_CMP_GE
 	
———————————————— deprecation end —
	An integer constant expression corresponding to the "greater than or equal to" comparison operation. See Section 10.10 for more detail about its use.

7   Library Handles

The OpenSHMEM library provides a set of predefined named constant handles. All named constants can be used in initialization expressions or assignments, but not necessarily in array declarations or as labels in *C* switch statements. This implies named constants to be link-time but not necessarily compile-time constants.

Handle	Description
C/C++: *SHMEM_TEAM_WORLD*	Handle of type *shmem_team_t* that corresponds to the default team of all PEs in the OpenSHMEM program. All point-to-point communication operations and collective synchronizations that do not specify a team are performed on the default team. See Section 10.4 for more detail about its use.

Handle	Description
C/C++: *SHMEM_TEAM_SHARED*	Handle of type *shmem_team_t* that corresponds to a team of PEs that share a memory domain. When this handle is used by some PE, it will refer to the team of all PEs that would return a non-null pointer from *shmem_ptr* for symmetric objects on that PE, and vice versa. This means that symmetric objects on each PE are directly load/store accessible by all PEs in the team. See Section 10.4 for more detail about its use.
C/C++: *SHMEM_CTX_DEFAULT*	Handle of type *shmem_ctx_t* that corresponds to the default communication context. All point-to-point communication operations and synchronizations that do not specify a context are performed on the default context. See Section 10.5 for more detail about its use.

8 Environment Variables

The OpenSHMEM specification provides a set of environment variables that allows users to configure the Open-SHMEM 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. All environment variables that start with *SMA_** are deprecated, but currently supported for backwards compatibility. If both *SHMEM_-* and *SMA_*-prefixed environment variables are set, then the value in the *SHMEM_*-prefixed environment variable establishes the controlling value. Refer to the *SMA_** Environment Variables deprecation rationale for more details.

Variable	Value	Description
SHMEM_VERSION	Any	Print the library version at start-up
SHMEM_INFO	Any	Print helpful text about all these environment variables
SHMEM_SYMMETRIC_SIZE	Non-negative integer	Number of bytes to allocate for symmetric heap
SHMEM_DEBUG	Any	Enable debugging messages

9 Error Handling

In many cases, OpenSHMEM routines will guarantee the correct completion of operations without any need for programs to check for error states, diagnose system problems, or retry operations. For example, there are no error codes returned for remote memory operations. The implementation is expected to internally attempt any feasible checking and recovery to best guarantee completion as specified. However, there are also cases where routines return error codes to allow programs to detect problems that may be correctable at the application layer, e.g. requests for system resources that cannot be fulfilled at runtime.

C/C++ routines that return an integer error code follow the convention that *0* indicates successful local completion of the operation. This is considered a best effort of the implementation to indicate that all required local operations have been performed correctly inside the routine and the internal OpenSHMEM state on the calling PE is consistent with the description of the routine and its arguments upon completion. Implementations may use an integer return value from a routine to define integer error codes specific to the implementation as long as those codes are not already explicitly defined for that routine.

Because OpenSHMEM defines asynchronous communication operations, errors may arise at any time as communications proceed. In these cases, the implementation might generate error messages or abort the application when errors occur. The OpenSHMEM specification cannot define these types of errors, and leaves it to the implementation to determine how these types of errors should be handled.

Collective operations involving many PEs may return values indicating success while other PEs are still executing the collective operation. By default, return values indicating success of a collective routine on one PE do not indicate

that all PEs involved in the collective operation will return from the routine successfully. If a collective routine provides any such global error checking behavior, it will be explicitly stated in the description of that routine.

If some routine specified in this document does not explicity state resulting error behavior when a program violates the routine assumptions and requirements, then the behavior is undefined. See Annex C for more details on undefined behavior in OpenSHMEM.

OpenSHMEM implementations are encouraged but not required to attempt to continue execution in the face of resource allocation errors, such as lack of network resources or memory resources. In these cases, if resource allocation fails inside a routine with an integer return code, library implementations should return some nonzero value, which may have implementation specific definition. If the routine has some other out parameter, such as pointer to a new memory allocation, routines may specify that the out parameter has some sentinel value to indicate failure to complete the operation.

10 OpenSHMEM Library API

10.1 Library Setup, Exit, and Query Routines

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

10.1.1 SHMEM_INIT

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

SYNOPSIS

C/C++:
```
void shmem_init(void);
```
— deprecation start ———
FORTRAN:
```
CALL SHMEM_INIT()
```
—— deprecation end —

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* or *shmem_init_thread* in the same program results in undefined behavior.

Return Values
   None.

Notes
   As of OpenSHMEM 1.2, the use of *start_pes* has been deprecated and calls to it should be replaced with calls to *shmem_init*. While support for *start_pes* is still required in OpenSHMEM libraries, users are encouraged to use *shmem_init*. An important difference between *shmem_init* and *start_pes* is that 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 results in a no-op.

EXAMPLES

   The following *shmem_init* example is for *C11* programs:

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

int main(void) {
    static int targ = 0;
```

```
        shmem_init();
        int me = shmem_my_pe();
        int receiver = 1 % shmem_n_pes();

        if (me == 0) {
            int src = 33;
            shmem_put(&targ, &src, 1, receiver);
        }

        shmem_barrier_all(); /* Synchronizes sender and receiver */

        if (me == receiver)
            printf("PE %d targ=%d (expect 33)\n", me, targ);

        shmem_finalize();
        return 0;
    }
```

10.1.2 SHMEM_MY_PE

Returns the number of the calling PE.

SYNOPSIS

    C/C++:

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

— deprecation start ————————————————————————————————

    FORTRAN:

```
INTEGER SHMEM_MY_PE, ME

ME = SHMEM_MY_PE()
```

———————————————————————————————— deprecation end —

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 1.2 the use of *_my_pe* has been dep-
        recated. 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.

10.1.3 SHMEM_N_PES

Returns the number of PEs running in a program.

SYNOPSIS

C/C++:
```
int shmem_n_pes(void);
```

— deprecation start ———

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

——————————————————————————————————————— deprecation end —

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 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_my_pe* and *shmem_n_pes* example is for *C/C++* programs:

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

int main(void)
{
  shmem_init();
  int me = shmem_my_pe();
  int npes = shmem_n_pes();
  printf("I am #%d of %d PEs executing this program\n", me, npes);
  shmem_finalize();
  return 0;
}
```

10.1.4 SHMEM_FINALIZE

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

SYNOPSIS

> **C/C++:**
> ```
> void shmem_finalize(void);
> ```
> — deprecation start ——
> **FORTRAN:**
> ```
> CALL SHMEM_FINALIZE()
> ```
> —— deprecation end —

DESCRIPTION

> **Arguments**
>> None.

> **API description**

>> *shmem_finalize* is a collective operation that ends the OpenSHMEM portion of a program previously initialized by *shmem_init* or *shmem_init_thread* and releases all 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* to ensure that pending communications are completed and that no resources are released until all PEs have entered *shmem_finalize*. This routine destroys all shareable contexts. The user is responsible for destroying all contexts with the *SHMEM_CTX_PRIVATE* option enabled prior to calling this routine; otherwise, the behavior is undefined. *shmem_finalize* must be the last OpenSHMEM library call encountered in the OpenSHMEM portion of a program. A call to *shmem_finalize* will release all resources initialized by a corresponding call to *shmem_init* or *shmem_init_thread*. All processes that represent the PEs will still exist after the call to *shmem_finalize* returns, but they will no longer have access to 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.

EXAMPLES

> The following finalize example is for *C11* programs:

> ```
> #include <stdio.h>
> #include <shmem.h>
>
> int main(void)
> {
> ```

```
static long x = 10101;                                                            1
long y = -1;                                                                       2
                                                                                  3
shmem_init();                                                                     4
int me = shmem_my_pe();                                                           5
int npes = shmem_n_pes();
                                                                                  6
if (me == 0)                                                                      7
    y = shmem_g(&x, npes-1);
                                                                                  8
printf("%d: y = %ld\n", me, y);                                                   9
                                                                                 10
shmem_finalize();
return 0;                                                                        11
}
```

10.1.5 SHMEM_GLOBAL_EXIT

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

SYNOPSIS

C11:
```
_Noreturn void shmem_global_exit(int status);
```

C/C++:
```
void shmem_global_exit(int status);
```

— deprecation start ——

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

——— deprecation end —

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 Open-SHMEM 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., that the program encountered an error or found a so-
lution. 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 lan-
guage 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 pro-
gram. 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)
{
    shmem_init();
    int me = shmem_my_pe();
    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);
    }
    shmem_finalize();
    return 0;
}
```

10.1.6 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);
```
—— deprecation start ——
FORTRAN:
```fortran
LOGICAL LOG, SHMEM_PE_ACCESSIBLE
INTEGER pe
LOG = SHMEM_PE_ACCESSIBLE(pe)
```
——— deprecation end ——

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 Open-SHMEM from the local PE. The *shmem_pe_accessible* routine returns a value indicating whether the remote PE is a process running from the same executable file as the local PE, thereby indicating whether full support for symmetric data objects, which may reside in either static memory or the symmetric heap, is available.

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

This routine may be particularly useful for hybrid programming with other communication libraries (such as *Message Passing Interface* (MPI)) or parallel languages. For example, when an MPI job uses *Multiple Program Multiple Data* (MPMD) mode, multiple executable MPI programs are executed as part of the same MPI job. In such cases, OpenSHMEM support may only be available between processes running from the same executable file. In addition, some environments may allow a hybrid job to span multiple network partitions. In such scenarios, OpenSHMEM support may only be available between PEs within the same partition.

10.1.7 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);
```
— deprecation start —————————————————————————————
FORTRAN:
```
LOGICAL LOG, SHMEM_ADDR_ACCESSIBLE
INTEGER pe
LOG = SHMEM_ADDR_ACCESSIBLE(addr, pe)
```
————————————————————————————————————— deprecation end —

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 Open-SHMEM routines from the specified remote PE.

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

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

This routine may be particularly useful for hybrid programming with other communication libraries (such as MPI) or parallel languages. For example, when an MPI job uses MPMD mode, multiple executable MPI programs may use OpenSHMEM routines. In such cases, 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.

10.1.8   SHMEM_PTR

Returns a local pointer to a symmetric data object on the specified PE.

SYNOPSIS

C/C++:
```
void *shmem_ptr(const void *dest, int pe);
```
— deprecation start ———
FORTRAN:
```
POINTER (PTR, POINTEE)
INTEGER pe
PTR = SHMEM_PTR(dest, pe)
```
——— deprecation end —

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. When 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.

The *shmem_ptr* routine can provide an efficient means to accomplish communication, for example when a sequence of reads and writes to a data object on a remote PE does not match the access pattern provided in an OpenSHMEM data transfer routine like *shmem_put* or *shmem_iget*.

Return Values
The address of the *dest* data object is returned when it is accessible using memory loads and stores. Otherwise, a null pointer 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:

```fortran
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 *C11*:

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

int main(void)
{
   static int dest[4];
   shmem_init();
   int me = shmem_my_pe();
   if (me == 0) { /* initialize PE 1's dest array */
      int* ptr = shmem_ptr(dest, 1);
      if (ptr == NULL)
         printf("can't use pointer to directly access PE 1's dest array\n");
      else
         for (int i = 0; i < 4; i++)
            *ptr++ = i + 1;
   }
   shmem_barrier_all();
   if (me == 1)
      printf("PE 1 dest: %d, %d, %d, %d\n",
         dest[0], dest[1], dest[2], dest[3]);
   shmem_finalize();
   return 0;
}
```

10.1.9 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);
```
—— deprecation start ——
FORTRAN:
```
INTEGER MAJOR, MINOR
CALL SHMEM_INFO_GET_VERSION(MAJOR, MINOR)
```
——— deprecation end ——

DESCRIPTION

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

API description

This routine returns the major and minor version of the OpenSHMEM Specification in use. For a given library implementation, the major and minor version returned by these calls are consistent with the library constants *SHMEM_MAJOR_VERSION* and *SHMEM_MINOR_VERSION*.

Return Values
None.

Notes
None.

10.1.10 SHMEM_INFO_GET_NAME

This routine returns the vendor defined name string that is consistent with the library constant *SHMEM_VENDOR_STRING*.

SYNOPSIS

C/C++:
```
void shmem_info_get_name(char *name);
```
—— deprecation start ——
FORTRAN:
```
CHARACTER *(*)NAME
CALL SHMEM_INFO_GET_NAME(NAME)
```
——— deprecation end ——

DESCRIPTION

Arguments
> **OUT**   *name*   The vendor defined string.

API description

> This routine returns the vendor defined name string of size defined by the library constant
> *SHMEM_MAX_NAME_LEN*. The program calling this function provides the *name* memory buffer of
> at least size *SHMEM_MAX_NAME_LEN*. The implementation copies the vendor defined string of size
> at most *SHMEM_MAX_NAME_LEN* to *name*. In *C/C++*, the string is terminated by a null charac-
> ter. In *Fortran*, the string of size less than *SHMEM_MAX_NAME_LEN* is padded with blank charac-
> ters up to size *SHMEM_MAX_NAME_LEN*. If the *name* memory buffer is provided with size less than
> *SHMEM_MAX_NAME_LEN*, behavior is undefined. For a given library implementation, the vendor string
> returned is consistent with the library constant *SHMEM_VENDOR_STRING*.

Return Values
> None.

Notes
> None.

10.1.11   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

> — deprecation start ——
>
> **C/C++:**
> ```
> void start_pes(int npes);
> ```
> ——————————————————————————————————————— deprecation end —
> — deprecation start ——
> **FORTRAN:**
> ```
> CALL START_PES(npes)
> ```
> ——————————————————————————————————————— deprecation end —

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*, *shmem_init*, or *shmem_init_thread* before calling any other OpenSHMEM routine.
>> Unlike *shmem_init* and *shmem_init_thread*, *start_pes* does not require a call to *shmem_finalize*. Instead,

the OpenSHMEM library is implicitly finalized when the program exits. Implicit finalization is collective and includes a global synchronization to ensure that all pending communication is completed before resources are released.

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 1.2 the use of *start_pes* has been deprecated. Although OpenSHMEM libraries are required to support the call, users are encouraged to use *shmem_init* or *shmem_init_thread* 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
```

10.2 Thread Support

This section specifies the interaction between the OpenSHMEM interfaces and user threads. It also describes the routines that can be used for initializing and querying the thread environment. There are four levels of threading defined by the OpenSHMEM specification.

SHMEM_THREAD_SINGLE
The OpenSHMEM program must not be multithreaded.

SHMEM_THREAD_FUNNELED
The OpenSHMEM program may be multithreaded. However, the program must ensure that only the main thread invokes the OpenSHMEM interfaces. The main thread is the thread that invokes either *shmem_init* or *shmem_init_thread*.

SHMEM_THREAD_SERIALIZED
The OpenSHMEM program may be multithreaded. However, the program must ensure that the OpenSHMEM interfaces are not invoked concurrently by multiple threads.

SHMEM_THREAD_MULTIPLE
    The OpenSHMEM program may be multithreaded and any thread may invoke the OpenSHMEM interfaces.

The following semantics apply to the usage of these models:

1. In the *SHMEM_THREAD_FUNNELED*, *SHMEM_THREAD_SERIALIZED*, and *SHMEM_THREAD_MULTIPLE* thread levels, the *shmem_init* and *shmem_finalize* calls must be invoked by the same thread.

2. Any OpenSHMEM operation initiated by a thread is considered an action of the PE as a whole. The symmetric heap and symmetric variables scope are not impacted by multiple threads invoking the OpenSHMEM interfaces. Each PE has a single symmetric data segment and symmetric heap that is shared by all threads within that PE. For example, a thread invoking a memory allocation routine such as *shmem_malloc* allocates memory that is accessible by all threads of the PE. The requirement that the same symmetric heap operations must be executed by all PEs in the same order also applies in a threaded environment. Similarly, the completion of collective operations is not impacted by multiple threads. For example, *shmem_barrier_all* is completed when all PEs enter and exit the *shmem_barrier_all* call, even though only one thread in the PE is participating in the collective call.

3. Blocking OpenSHMEM calls will only block the calling thread, allowing other threads, if available, to continue executing. The calling thread will be blocked until the event on which it is waiting occurs. Once the blocking call is completed, the thread is ready to continue execution. A blocked thread will not prevent progress of other threads on the same PE and will not prevent them from executing other OpenSHMEM calls when the thread level permits. In addition, a blocked thread will not prevent the progress of OpenSHMEM calls performed on other PEs.

4. In the *SHMEM_THREAD_MULTIPLE* thread level, all OpenSHMEM calls are thread-safe. Any two concurrently running threads may make OpenSHMEM calls and the outcome will be as if the calls executed in some order, even if their execution is interleaved.

5. In the *SHMEM_THREAD_SERIALIZED* and *SHMEM_THREAD_MULTIPLE* thread levels, if multiple threads call collective routines, including the symmetric heap management routines, it is the programmer's responsibility to ensure the correct ordering of collective calls.

10.2.1 SHMEM_INIT_THREAD

Initializes the OpenSHMEM library, similar to *shmem_init*, and performs any initialization required for supporting the provided thread level.

SYNOPSIS

    C/C++:
```
int shmem_init_thread(int requested, int *provided);
```

DESCRIPTION

    Arguments
IN	*requested*	The thread level support requested by the user.
OUT	*provided*	The thread level support provided by the OpenSHMEM implementation.

    API description

        shmem_init_thread initializes the OpenSHMEM library in the same way as *shmem_init*. In addition, *shmem_init_thread* also performs the initialization required for supporting the provided thread level. The argument *requested* is used to specify the desired level of thread support. The argument *provided*

returns the support level provided by the library. The allowed values for *provided* and *requested* are *SHMEM_THREAD_SINGLE*, *SHMEM_THREAD_FUNNELED*, *SHMEM_THREAD_SERIALIZED*, and *SHMEM_THREAD_MULTIPLE*.

An OpenSHMEM program is initialized either by *shmem_init* or *shmem_init_thread*. Once an Open-SHMEM library initialization call has been performed, a subsequent initialization call in the same program results in undefined behavior. If the call to *shmem_init_thread* is unsuccessful in allocating and initializing resources for the OpenSHMEM library, then the behavior of any subsequent call to the OpenSHMEM library is undefined.

Return Values

    shmem_init_thread returns 0 upon success; otherwise, it returns a non-zero value.

Notes

    The OpenSHMEM library can be initialized either by *shmem_init* or *shmem_init_thread*. If the Open-SHMEM library is initialized by *shmem_init*, the library implementation can choose to support any one of the defined thread levels.

10.2.2 SHMEM_QUERY_THREAD

Returns the level of thread support provided by the library.

SYNOPSIS

    C/C++:
```
void shmem_query_thread(int *provided);
```

DESCRIPTION

    Arguments

        OUT   *provided*   The thread level support provided by the OpenSHMEM implementation.

    API description

    The *shmem_query_thread* call returns the level of thread support currently being provided. The value returned will be same as was returned in *provided* by a call to *shmem_init_thread*, if the OpenSHMEM library was initialized by *shmem_init_thread*. If the library was initialized by *shmem_init*, the implementation can choose to provide any one of the defined thread levels, and *shmem_query_thread* returns this thread level.

    Return Values

    None.

    Notes

    None.

10.3 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.

10.3.1 SHMEM_MALLOC, SHMEM_FREE, SHMEM_REALLOC, SHMEM_ALIGN

Collective 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*	Pointer to a block within the symmetric heap.
IN	*alignment*	Byte alignment of the block allocated from the symmetric heap.

API description

The *shmem_malloc*, *shmem_free*, *shmem_realloc*, and *shmem_align* routines are collective operations that require participation by all PEs.

The *shmem_malloc* routine returns a pointer to a block of at least *size* bytes, which shall be suitably aligned so that it may be assigned to a pointer to any type of object. This space is allocated from the symmetric heap (in contrast to *malloc*, which allocates from the private heap). When *size* is zero, the *shmem_malloc* routine performs no action and returns a null pointer.

The *shmem_align* routine allocates a block in the symmetric heap that has a byte alignment specified by the *alignment* argument. The value of *alignment* shall be a multiple of *sizeof(void *)* that is also a power of two. Otherwise, the behavior is undefined. When *size* is zero, the *shmem_align* routine performs no action and returns a null pointer.

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 is performed.

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_align*, *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. When no action is performed, these routines return without performing a barrier. Otherwise, each of these routines includes at least one call to a procedure that is semantically equivalent to *shmem_barrier_all*: *shmem_malloc* and *shmem_align* call a barrier on exit; *shmem_free* calls a barrier on entry; and *shmem_realloc* may call barriers on both entry and exit, depending on whether an existing allocation is modified and whether new memory is allocated, respectively. 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 implicit barriers performed by these routines quiet the default context. It is the user's responsibility to ensure that no communication operations involving the given memory block are pending on other contexts prior to calling the *shmem_free* and *shmem_realloc* routines. The user is also responsible for calling these routines with identical argument(s) on all PEs; if differing *ptr*, *size*, or *alignment* arguments are used, the behavior of the call and any subsequent OpenSHMEM calls is 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, all PEs return a null pointer.

The *shmem_align* routine returns an aligned pointer whose value is a multiple of *alignment*; otherwise, it returns a null pointer.

Notes

As of OpenSHMEM 1.2 the use of *shmalloc*, *shmemalign*, *shfree*, and *shrealloc* has been deprecated. Although OpenSHMEM libraries are required to support the calls, 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 specify the size of the heap using the *SHMEM_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).

When the *ptr* argument in a call to *shmem_realloc* corresponds to a buffer allocated using *shmem_align*, the buffer returned by *shmem_realloc* is not guaranteed to maintain the alignment requested in the original call to *shmem_align*.

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 $O(N)$ memory translation tables, where N is the number of PEs. 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.

10.3.2 SHMEM_CALLOC

Allocate a zeroed block of symmetric memory.

SYNOPSIS

C/C++:
```
void *shmem_calloc(size_t count, size_t size);
```

DESCRIPTION

Arguments

IN	*count*	The number of elements to allocate.
IN	*size*	The size in bytes of each element to allocate.

API description

The *shmem_calloc* routine is a collective operation that allocates a region of remotely-accessible memory for an array of *count* objects of *size* bytes each and returns a pointer to the lowest byte address of the allocated symmetric memory. The space is initialized to all bits zero.

If the allocation succeeds, the pointer returned shall be suitably aligned so that it may be assigned to a pointer to any type of object. If the allocation does not succeed, or either *count* or *size* is *0*, the return value is a null pointer.

The values for *count* and *size* shall each be equal across all PEs calling *shmem_calloc*; otherwise, the behavior is undefined.

When *count* or *size* is *0*, the *shmem_calloc* routine returns without performing a barrier. Otherwise, this routine calls a procedure that is semantically equivalent to *shmem_barrier_all* on exit.

Return Values

The *shmem_calloc* routine returns a pointer to the lowest byte address of the allocated space; otherwise, it returns a null pointer.

Notes

None.

10.3.3 SHPALLOC

Allocates a block of memory from the symmetric heap.

SYNOPSIS

— deprecation start —————————————————————————————————————

FORTRAN:
```
POINTER (addr, A(1))
INTEGER length, errcode, abort
CALL SHPALLOC(addr, length, errcode, abort)
```
————————————————————————————————————— deprecation end —

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, array *A* can be used 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 *SHMEM_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.

10.3.4   SHPCLMOVE

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

SYNOPSIS

— deprecation start —————————————————————————————
FORTRAN:
```
POINTER (addr, A(1))
INTEGER length, status, abort
CALL SHPCLMOVE(addr, length, status, abort)
```
——————————————————————————————— deprecation end —

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.

10.3.5 SHPDEALLC

Returns a memory block to the symmetric heap.

SYNOPSIS

— deprecation start ——————————————————————
FORTRAN:
```
POINTER (addr, A(1))
INTEGER errcode, abort
CALL SHPDEALLC(addr, errcode, abort)
```
——————————————————————————— deprecation end —

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.

10.4   Team Management Routines

The PEs in an OpenSHMEM program communicate using either point-to-point routines, which specify the PE number of the target PE, or collective routines, which operate over a set of PEs. In OpenSHMEM, teams allow programs to group a set of PEs for communication. Team-based collective communications operate across all the PEs in a valid team. Point-to-point communication can make use of team-relative PE numbering through team-based contexts (see Section 10.5) or PE number translation.

Predefined and Program-Defined Teams

An OpenSHMEM team may be predefined (i.e., provided by the OpenSHMEM library) or defined by the OpenSHMEM program. A program-defined team is created by "splitting" a parent team into one or more new teams—each with some subset of PEs of the parent team—via one of the *shmem_team_split_* * routines.

   All predefined teams are valid for the duration of the OpenSHMEM portion of an application. Any team successfully created by a *shmem_team_split_* * routine is valid until it is destroyed. All valid teams have a least one member.

Team Handles

A "team handle" is an opaque object with type *shmem_team_t* that is used to reference a team. Team handles are not remotely accessible objects The predefined teams may be accessed via the team handles listed in Section 7.

   OpenSHMEM communication routines that do not accept a team handle argument operate on the default team, which may be accessed through the *SHMEM_TEAM_WORLD* handle. The default team encompasses the set of all PEs in the OpenSHMEM program, and a PE number in the default team is the same as the value returned by *shmem_my_pe*.

   A team handle may be initialized to or assigned the value *SHMEM_TEAM_INVALID* to indicate that handle does not reference a valid team. When managed in this way, applications can use an equality comparison to test whether a given team handle references a valid team.

Thread Safety

When it is allowed by the threading model provided by the OpenSHMEM library, a team may be used concurrently in non-collective operations (e.g., *shmem_team_my_pe*) by multiple threads within the PE where it was created. For collective operations, a team may not be used concurrently by multiple threads in the same PE.

Collective Ordering

In OpenSHMEM, a team object encapsulates resources used to communicate between PEs in collective operations. When calling multiple subsequent collective operations on a team, the collective operations—along with any relevant team based resources—are matched across the PEs in the team based on ordering of collective routine calls. It is the responsibility of the OpenSHMEM program to ensure the same ordering of collective routine calls across all PEs in a team.

There is no need for explicit synchronization between subsequent calls to collective routines across the team, except in the special case discussed below for team creation of overlapping child teams from a common parent team.

A full discussion of collective semantics follows in Section 10.9.

Team Creation

Team creation is a collective operation on the parent team object. New teams result from a *shmem_team_split_** routine, which takes a parent team and other arguments and produces new teams that are a subset of the parent team. Teams that are created by a *shmem_team_split_** routine may be provided a configuration argument that specifies attributes of each new team. This configuration argument is of type *shmem_team_config_t*, which is detailed further in Section 10.4.3.

As with any collective routine on a team, the program must ensure that there are no simultaneous split operations occurring on the same parent team on a given PE, i.e. in separate threads.

As with any collective routine on a team, team creation is matched across PEs based on ordering. So, team creation events must occur in the same order on all PEs in the parent team. Additionally, there must not be team creation operations from the same parent team simultaneously occurring that involve the same PEs in any resulting child teams.

The following rule of practice will avoid any conflicts on team object resources during team creation:

When a parent team is split multiple times, and the resulting child teams have overlapping membership, the program must call the shmem_team_sync routine on the parent team between subsequent calls to split routines.

Upon completion of a team creation operation, any resulting child teams will be immediately usable for any team-based operations, including creating new child teams, without any intervening synchronization.

10.4.1 SHMEM_TEAM_MY_PE

Returns the number of the calling PE within a specified team.

SYNOPSIS

C/C++:
```
int shmem_team_my_pe(shmem_team_t team);
```

DESCRIPTION

Arguments

IN	*team*	An OpenSHMEM team handle.

API description

When *team* specifies a valid team, the *shmem_team_my_pe* routine returns the number of the calling PE within the specified team. The number is an integer between 0 and $N-1$ for a team of size N. Each member of the team has a unique number.

When *team* specifies an invalid team, if *team* compares equal to *SHMEM_TEAM_INVALID*, then the value *-1* is returned; otherwise, the behavior is undefined.

Return Values

The number of the calling PE within the specified team, or the value *-1* if the team handle compares equal to *SHMEM_TEAM_INVALID*.

Notes

For the default team, this routine will return the same value as *shmem_my_pe*.

10.4.2   SHMEM_TEAM_N_PES

Returns the number of PEs in a specified team.

SYNOPSIS

C/C++:
```
int shmem_team_n_pes(shmem_team_t team);
```

DESCRIPTION

Arguments
    IN   *team*   An OpenSHMEM team handle.

API description

When *team* specifies a valid team, the *shmem_team_n_pes* routine returns the number of PEs in the team. This will always be a value between 1 and *N*, where *N* is the total number of PEs running in the Open-SHMEM program.

When *team* specifies an invalid team, if *team* compares equal to *SHMEM_TEAM_INVALID*, then the value *-1* is returned; otherwise, the behavior is undefined.

Return Values

The number of PEs in the specified team, or the value *-1* if the team handle compares equal to *SHMEM_TEAM_INVALID*.

Notes

For the default team, this routine will return the same value as *shmem_n_pes*.

10.4.3   SHMEM_TEAM_CONFIG_T

A structure type representing team configuration arguments

SYNOPSIS

C/C++:

```
typedef struct {                                          1
  int num_contexts;                                       2
} shmem_team_config_t;                                    3
                                                          4
```

DESCRIPTION

Arguments
None.

API description

A team configuration argument acts as an input *shmem_team_split_** routines. It specifies the requested capabilities of the team to be created.

The *num_contexts* member specifies the total number of simultaneously existing contexts that the program requests to create from this team. These contexts may be created in any number of threads. Successful creation of a team configured with *num_contexts* of *N* means that the implementation will make a best effort to reserve enough resources to allow the team to have *N* contexts created from the team in existance at any given time. It is not a guaruntee that *N* calls to *shmem_team_create_ctx* will succeed. See Section 10.5 for more on communication contexts and Section 10.5.2 for team-based context creation.

When using the configuration structure to create teams, a mask parameter controls which fields to use. Any configuration parameter value that is not indicated in the mask will be ignored, and the default value will be used instead. Therefore, a program does not have to set all fields in the config struct; only those for which it does not want the default values.

A configuration mask value is created by combining individual field masks with through a bitwise OR operation of the following library constants:

SHMEM_TEAM_NUM_CONTEXTS The team should be created using the value of the *num_contexts* member of the configuration parameter *config* as a requirement.

A configuration mask value of *0* indicates that the team should be created with the default values for all configuration parameters.

The default values for configuration parameters are:

num_contexts = *0*   By default, no contexts can be created on a new team

Notes
None.

10.4.4 SHMEM_TEAM_GET_CONFIG

Return the configuration parameters of a given team

SYNOPSIS

C/C++:
```
int shmem_team_get_config(shmem_team_t team, shmem_team_config_t *config);
```

DESCRIPTION

Arguments

| IN | *team* | An OpenSHMEM team handle. |
| OUT | *config* | A pointer to the configuration parameters for the given team. |

API description

> *shmem_team_get_config* returns through the *config* argument the configuration parameters of the given team, which were assigned according to input configuration parameters when the team was created.
>
> When *team* specifies an invalid team, if *team* compares equal to *SHMEM_TEAM_INVALID*, then no operation is performed; otherwise, the behavior is undefined.

Return Values

> If *team* does not compare equal to *SHMEM_TEAM_INVALID*, then *shmem_team_get_config* returns *0*; otherwise, returns nonzero.

Notes

> None.

10.4.5   SHMEM_TEAM_TRANSLATE_PE

Translate a given PE number from one team to the corresponding PE number in another team.

SYNOPSIS

> **C/C++:**
> ```
> int shmem_team_translate_pe(shmem_team_t src_team, int src_pe,
>     shmem_team_t dest_team);
> ```

DESCRIPTION

> **Arguments**
>
> | IN | *src_team* | A valid SHMEM team handle. |
> | IN | *src_pe* | A PE number in src_team. |
> | IN | *dest_team* | A valid SHMEM team handle. |

API description

> The *shmem_team_translate_pe* routine will translate a given PE number to the corresponding PE number in another team. Specifically, given the *src_pe* in *src_team*, this routine returns that PE's number in *dest_team*. If *src_pe* is not a member of both the *src_team* and *dest_team*, a value of *-1* is returned.
>
> If either of the *src_team* or *dest_team* handle is invalid, the behavior is undefined.

Return Values

> The specified PE's number in the *dest_team*, or a value of *-1* if any team handle arguments are invalid or the *src_pe* is not in both the source and destination teams.

Notes

> If *SHMEM_TEAM_WORLD* is provided as the *dest_team* parameter, this routine acts as a global PE number translator and will return the corresponding *SHMEM_TEAM_WORLD* number.

EXAMPLES

The following example demonstrates the use of the team PE number translation routine. The program makes a new team of all of the even number PEs in the default team. Then, all PEs in the new team acquire their PE number in the new team and translate it to the PE number in the default team.

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

int main(void)
{
    int                     my_pe;
    int                     n_pes;
    int                     t_pe;
    int     t_global;
    shmem_team_t            new_team;
    shmem_team_config_t *config;

    shmem_init();
    config = NULL;
    my_pe  = shmem_my_pe();
    n_pes  = shmem_n_pes();

    shmem_team_split_strided(SHMEM_TEAM_WORLD, 0, 2, (n_pes + 1) / 2,
                             config, 0, &new_team);

    if (new_team != SHMEM_TEAM_INVALID) {
        t_pe     = shmem_team_my_pe(new_team);
        t_global = shmem_team_translate_pe(new_team, t_pe, SHMEM_TEAM_WORLD);

        if (t_global != my_pe) {
            shmem_global_exit(1);
        }
    }

    shmem_finalize();
    return 0;
}
```

10.4.6   SHMEM_TEAM_SPLIT_STRIDED

Create a new OpenSHMEM team from a subset of the existing parent team PEs, where the subset is defined by the PE triplet (*PE_start*, *PE_stride*, and *PE_size*) supplied to the routine.

SYNOPSIS

C/C++:
```c
int shmem_team_split_strided(shmem_team_t parent_team, int PE_start, int PE_stride,
    int PE_size, const shmem_team_config_t *config, long config_mask, shmem_team_t
    *new_team);
```

DESCRIPTION

Arguments

IN	*parent_team*	An OpenSHMEM team.
IN	*PE_start*	The lowest PE number of the subset of PEs from the parent team that will form the new team.
IN	*PE_stride*	The stride between team PE numbers in the parent team that comprise the subset of PEs that will form the new team.

IN	*PE_size*	The number of PEs from the parent team in the subset of PEs that will form the new team.
IN	*config*	A pointer to the configuration parameters for the new team.
IN	*config_mask*	The bitwise mask representing the set of configuration parameters to use from *config*.
OUT	*new_team*	A new OpenSHMEM team handle, representing a PE subset of all the PEs in the parent team that is created from the PE triplet provided.

API description

The *shmem_team_split_strided* routine is a collective routine. It creates a new OpenSHMEM team from a subset of the existing parent team, where the subset is defined by the PE triplet (*PE_start*, *PE_stride*, and *PE_size*) supplied to the routine.

This routine must be called by all PEs contained in the PE triplet specification. It may be called by additional PEs not included in the triplet specification, but for those PEs a *new_team* value of *SHMEM_TEAM_INVALID* is returned. All PEs must provide the same values for the PE triplet. This routine will return a *new_team* containing the PE subset specified by the triplet and ordered by the existing global PE number.

The *config* argument specifies team configuration parameters, which are described in Section 10.4.3.

The *config_mask* argument is a bitwise mask representing the set of configuration parameters to use from *config*. A *config_mask* value of *0* indicates that the team should be created with the default values for all configuration parameters. See Section 10.4.3 for field mask names and default configuration parameters.

When *parent_team* specifies an invalid team, if *parent_team* compares equal to *SHMEM_TEAM_INVALID*, then no new team will be created and *new_team* will be assigned the value *SHMEM_TEAM_INVALID*; otherwise, the behavior is undefined.

If an invalid PE triplet is provided, then the *new_team* will not be created.

If *new_team* cannot be created, then it will be assigned the value *SHMEM_TEAM_INVALID*.

Return Values

Zero on successful creation of *new_team*, nonzero otherwise.

Notes

It is important to note the use of the less restrictive *PE_stride* argument instead of *logPE_stride*. This method of creating a team with an arbitrary set of PEs is inherently restricted by its parameters, but allows for many additional use-cases over using a *logPE_stride* parameter, and may provide an easier transition for existing OpenSHMEM programs to create and use OpenSHMEM teams.

See the description of team handles and predefined teams at the top of Section 10.4 for more information about semantics and usage.

EXAMPLES

The following example demonstrates the use of strided split in a *C11* program. The program creates a new team of all even number PEs from the default team, then retrieves the PE number and team size on all PEs that are members of the new team.

```
/*
 * OpenSHMEM shmem_team_split_strided example to create a team of all even
 * ranked PEs from SHMEM_TEAM_WORLD
```

```
 */

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

int main(int argc, char *argv[])
{
    int                 rank, npes;
    int                 t_pe, t_size;
    shmem_team_t        new_team;
    shmem_team_config_t *config;

    shmem_init();
    config = NULL;
    rank   = shmem_my_pe();
    npes   = shmem_n_pes();

    shmem_team_split_strided(SHMEM_TEAM_WORLD, 0, 2, npes / 2, config, 0,
                             &new_team);

    if (new_team != SHMEM_TEAM_INVALID) {
        t_size = shmem_team_n_pes(new_team);
        t_pe   = shmem_team_my_pe(new_team);

        if ((rank % 2 != 0) || (rank / 2 != t_pe) || (npes / 2 != t_size)) {
            shmem_global_exit(1);
        }
    }

    shmem_finalize();
    return 0;
}
```

10.4.7   SHMEM_TEAM_SPLIT_2D

Create two new teams by splitting an existing parent team into two subsets based on a 2D Cartesian space defined
by the *xrange* argument and a *y* dimension derived from *xrange* and the parent team size. These ranges describe the
Cartesian space in *x*- and *y*-dimensions.

SYNOPSIS

   C/C++:
```
int shmem_team_split_2d(shmem_team_t parent_team, int xrange,
    shmem_team_config_t *xaxis_config, long xaxis_mask, shmem_team_t *xaxis_team,
    shmem_team_config_t *yaxis_config, long yaxis_mask, shmem_team_t *yaxis_team);
```

DESCRIPTION

   Arguments

IN	*parent_team*	A valid OpenSHMEM team. Any predefined teams, such as *SHMEM_TEAM_WORLD*, may be used, or any team created by the user.	
IN	*xrange*	A nonnegative integer representing the number of elements in the first dimension.	
INOUT	*xaxis_config*	A pointer to the configuration parameters for the new *x*-axis team.	
IN	*xaxis_mask*	The bitwise mask representing the set of configuration parameters to use from *xaxis_config*.	

OUT	*xaxis_team*	A new PE team handle representing a PE subset consisting of all the PEs that have the same coordinate along the *x*-axis as the calling PE.
INOUT	*yaxis_config*	A pointer to the configuration parameters for the new *y*-axis team.
IN	*yaxis_mask*	The bitwise mask representing the set of configuration parameters to use from *yaxis_config*.
OUT	*yaxis_team*	A new PE team handle representing a PE subset consisting of all the PEs that have the same coordinate along the *y*-axis as the calling PE.

API description

The *shmem_team_split_2d* routine is a collective routine. It creates two new teams by splitting an existing parent team into up to two subsets based on a 2D Cartesian space. The user provides the size of the *x* dimension, which is then used to derive the size of the *y* dimension based on the size of the parent team. The size of the *y* dimension will be equal to $\lceil N \div xrange \rceil$, where N is the size of the parent team. In other words, $xrange \times yrange \geq N$, so that every PE in the parent team has a unique *(x,y)* location the 2D Cartesian space.

The mapping of PE number to coordinates is $(x,y) = (pe \mod xrange, \lfloor pe \div xrange \rfloor)$, where *pe* is the PE number in the parent team. So, if $xrange = 3$, then the first 3 PEs in the parent team will form the first *xteam*, the second three PEs in the parent team form the second *xteam*, and so on.

Thus, after the split operation, each of the new *xteam*s will contain all PEs that have the same coordinate along the *y*-axis as the calling PE. Each of the new *yteam*s will contain all PEs with the same coordinate along the *x*-axis as the calling PE.

The PEs are numbered in the new teams based on the coordinate of the PE along the given axis. So, another way to think of the result of the split operation is that the value returned by *shmem_team_my_pe((*xteam)) is the x-coordinate and the value returned by *shmem_team_my_pe((*yteam)) is the y-coordinate of the calling PE.

Any valid OpenSHMEM team can be used as the parent team. This routine must be called by all PEs in the parent team. The value of *xrange* must be nonnegative and all PEs in the parent team must pass the same value for *xrange*. None of the parameters need to reside in symmetric memory.

The *xaxis_config* and *yaxis_config* arguments specify team configuration parameters for the *x*- and *y*-axis teams, respectively. These parameters are described in Section 10.4.3. All PEs that will be in the same resultant team must specify the same configuration parameters. The PEs in the parent team *do not* have to all provide the same parameters for new teams.

The *xaxis_mask* and *xaxis_mask* arguments are a bitwise masks representing the set of configuration parameters to use from *xaxis_config* and *yaxis_config*, respectively. A mask value of *0* indicates that the team should be created with the default values for all configuration parameters. See Section 10.4.3 for field mask names and default configuration parameters.

If *parent_team* is an invalid team handle, the behavior is undefined.

If *parent_team* compares equal to *SHMEM_TEAM_INVALID*, no new teams will be created, and both *xaxis_team* and *yaxis_team* will be assigned the value *SHMEM_TEAM_INVALID*.

If either team cannot be created, that team will be assigned the value *SHMEM_TEAM_INVALID*.

Return Values

Zero on successful creation of both *xaxis_team* and *yaxis_team*, nonzero otherwise.

Notes

Since the split may result in a 2D space with more points than there are members of the parent team, there may be a final, incomplete row of the 2D mapping of the parent team. This means that the resultant *yteam*s

may vary in size by up to 1 PE, and that there may be one resultant *xteam* of smaller size than all of the other *xteam*s.

The following grid shows the 12 teams that would result from splitting a parent team of size 10 with *xrange* of 3. The numbers in the grid cells are the PE numbers in the parent team. The rows are the *xteam*s. The columns are the *yteam*s.

	yteam x=0	yteam x=1	yteam x=2
xteam, y=0	0	1	2
xteam, y=1	3	4	5
xteam, y=2	6	7	8
xteam, y=3	9		

It would be legal, for example, if PEs 0, 3, 6, 9 specified a different value for *yaxis_config* than all of the other PEs, as long as the configuration parameters match for all PEs in each of the new teams.

See the description of team handles and predefined teams at the top of section 10.4 for more information about team handle semantics and usage.

EXAMPLES

The following example demonstrates the use of 2D Cartesian split in a *C11* program. This example shows how multiple 2D splits can be used to generate a 3D Cartesian split. This method can be extrapolated to generate splits of any number of dimensions.

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

int main(void)
{
  int xdim = 3;
  int ydim = 4;

  shmem_init();
  int pe = shmem_my_pe();
  int npes = shmem_n_pes();

  if (npes < (xdim*ydim)) {
    printf ("Not enough PEs to create 4x3xN layout\n");
    exit(1);
  }

  int zdim = (npes / (xdim*ydim)) + ( ((npes % (xdim*ydim)) > 0) ? 1 : 0 );
  shmem_team_t xteam, yzteam, yteam, zteam;

  shmem_team_split_2d(SHMEM_TEAM_WORLD, xdim, NULL, 0, &xteam, NULL, 0, &yzteam);
  // No synchronization is needed between these split operations
  // yzteam is immediately ready to be used in collectives
  shmem_team_split_2d(yzteam, ydim, NULL, 0, &yteam, NULL, 0, &zteam);

  // We don't need the yzteam anymore
  shmem_team_destroy(yzteam);

  int my_x = shmem_team_my_pe(xteam);
  int my_y = shmem_team_my_pe(yteam);
  int my_z = shmem_team_my_pe(zteam);

  for (int zdx = 0; zdx < zdim; zdx++)
    for (int ydx = 0; ydx < ydim; ydx++)
      for (int xdx = 0; xdx < xdim; xdx++) {
        if ((my_x == xdx) && (my_y == ydx) && (my_z == zdx)) {
          printf ("(%d, %d, %d) is me = %d\n", my_x, my_y, my_z, pe);
        }
```

```
        shmem_team_sync(SHMEM_TEAM_WORLD);
    }

  shmem_finalize();
}


/*
/* Example split of SHMEM_TEAM_WORLD, size 16 into 3D
/* xdim = 3, ydim = 4 -> final dimensions are 3x4x2
/*
/* First split of SHMEM_TEAM_WORLD, xdim=3
/* results in 6 xteams and 3 yzteam
/**********************************************
/*        x=0 | x=1 | x=2 |
/*        -------------------
/* yz=0 |   0 |   1 |   2 | <-- xteam
/* yz=1 |   3 |   4 |   5 | <-- xteam
/* yz=2 |   6 |   7 |   8 | <-- xteam
/* yz=3 |   9 |  10 |  11 | <-- xteam
/* yz=4 |  12 |  13 |  14 | <-- xteam
/* yz=5 |  15 |         | <-- xteam
/*           ^     ^     ^
/*          { yzteams are columns }
/**********************************************
/*
/* Second split of yzteam for x=0, ydim=4
/* results in 2 yteams and 4 zteams
/**********************************************
/*        y=0 | y=1 | y=2 | y=3 |
/*        -------------------------
/* z=0 |   0 |   3 |   6 |   9 | <-- yteam
/* z=1 |  12 |  15 |         | <-- yteam
/*           ^     ^     ^     ^
/*          { zteams are columns }
/**********************************************
/*
/* Second split of yzteam for x=1, ydim=4
/* results in 2 yteams and 4 zteams
/**********************************************
/*        y=0 | y=1 | y=2 | y=3 |
/*        -------------------------
/* z=0 |   1 |   4 |   7 |  10 | <-- yteam
/* z=1 |  13 |     |         | <-- yteam
/*           ^     ^     ^     ^
/*          { zteams are columns }
/**********************************************
/*
/* Second split of yzteam for x=2, ydim=4
/* results in 2 yteams and 4 zteams
/**********************************************
/*        y=0 | y=1 | y=2 | y=3 |
/*        -------------------------
/* z=0 |   2 |   5 |   8 |  11 | <-- yteam
/* z=1 |  14 |     |         | <-- yteam
/*           ^     ^     ^     ^
/*          { zteams are columns }
/**********************************************
/*
/* Final number of teams for each dimension:
/* 6 xteams, these are teams where (z,y) is fixed and x varies
/* 6 yteams, these are teams where (x,z) is fixed and y varies
/* 12 zteams, these are teams where (x,y) is fixed and z varies
/*
/* Expected output:
/* (0, 0, 0) is me = 0
/* (1, 0, 0) is me = 1
/* (2, 0, 0) is me = 2
```

```
/* (0, 1, 0) is me = 3
/* (1, 1, 0) is me = 4
/* (2, 1, 0) is me = 5
/* (0, 2, 0) is me = 6
/* (1, 2, 0) is me = 7
/* (2, 2, 0) is me = 8
/* (0, 3, 0) is me = 9
/* (1, 3, 0) is me = 10
/* (2, 3, 0) is me = 11
/* (0, 0, 1) is me = 12
/* (1, 0, 1) is me = 13
/* (2, 0, 1) is me = 14
/* (0, 1, 1) is me = 15
*/
```

10.4.8 SHMEM_TEAM_DESTROY

Destroy an existing team.

SYNOPSIS

C/C++:
```
void shmem_team_destroy(shmem_team_t team);
```

DESCRIPTION

Arguments
IN   *team*   An OpenSHMEM team handle.

API description

The *shmem_team_destroy* routine destroys an existing team. This is a collective call, in which every member of the team being destroyed needs to participate. This will free all internal resources associated with the team. Upon return, the team handle can no longer be used for team API calls.

It is considered erroneous to free *SHMEM_TEAM_WORLD* or any other predefined team.

When *team* specifies an invalid team, if *team* compares equal to *SHMEM_TEAM_INVALID*, then no operation is performed; otherwise, the behavior is undefined.

Team destruction assumes that any resources explicitly created from the team, such as contexts created from the team, have already been released through the appropriate function, such as destroying the context. If there are any objects or resources explicitly created from the team that have not been explicitly released before *shmem_team_destroy* is called, behavior is undefined.

Return Values
None.

Notes
None.

10.5   Communication Management Routines

All OpenSHMEM *Remote Memory Access* (RMA), *Atomic Memory Operation* (AMO), and memory ordering routines must be performed on a valid communication context. The communication context defines an independent ordering and completion environment, allowing users to manage the overlap of communication with computation and also to manage communication operations performed by separate threads within a multithreaded PE. For example, in single-threaded environments, contexts may be used to pipeline communication and computation. In multithreaded environments, contexts may additionally provide thread isolation, eliminating overheads resulting from thread interference.

A specific communication context is referenced through a context handle, which is passed as an argument in the *C shmem_ctx_* * and type-generic API routines. API routines that do not accept a context handle argument operate on the default context. The default context can be used explicitly through the *SHMEM_CTX_DEFAULT* handle. Context handles are of type *shmem_ctx_t* and may be used for language-level assignment and equality comparison.

The default context is valid for the duration of the OpenSHMEM portion of an application. Contexts created by a successful call to *shmem_ctx_create* remain valid until they are destroyed. A handle value that does not correspond to a valid context is considered to be invalid, and its use in RMA and AMO routines results in undefined behavior. A context handle may be initialized to or assigned the value *SHMEM_CTX_INVALID* to indicate that handle does not reference a valid communication context. When managed in this way, applications can use an equality comparison to test whether a given context handle references a valid context.

Every communication context is associated with a team. This association is established at context creation. Communication contexts created by *shmem_ctx_create* are associated with the default team, while contexts created by *shmem_team_create_ctx* are associated with and created from a team specified at context creation. The default context is associated with the default team. A context's associated team specifies the set of PEs over which PE-specific routines that operate on a communication context, explicitly or implicitly, are performed. All point-to-point routines that operate on this context will do so with respect to the team-relative PE numbering of the associated team.

10.5.1   SHMEM_CTX_CREATE

Create a communication context locally.

SYNOPSIS

> **C/C++:**
> ```
> int shmem_ctx_create(long options, shmem_ctx_t *ctx);
> ```

DESCRIPTION

> **Arguments**
>
> | | | |
> |---|---|---|
> | **IN** | *options* | The set of options requested for the given context. Multiple options may be requested by combining them with a bitwise OR operation; otherwise, *0* can be given if no options are requested. |
> | **OUT** | *ctx* | A handle to the newly created context. |

> **API description**
>
> The *shmem_ctx_create* routine creates a new communication context and returns its handle through the *ctx* argument. If the context was created successfully, a value of zero is returned and the context handle pointed to by *ctx* specifies a valid context; otherwise, a nonzero value is returned and the context handle pointed to by *ctx* is not modified. An unsuccessful context creation call is not treated as an error and the OpenSHMEM library remains in a correct state. The creation call can be reattempted with different options or after additional resources become available.
>
> A newly created communication context has an initial association with the default team. All OpenSHMEM routines that operate on this context will do so with respect to the associated PE team. That is, all point-to-point routines operating on this context will use team-relative PE numbering.

By default, contexts are *shareable* and, when it is allowed by the threading model provided by the Open-
SHMEM library, they can be used concurrently by multiple threads within the PE where they were created.
The following options can be supplied during context creation to restrict this usage model and enable per-
formance optimizations. When using a given context, the application must comply with the requirements of
all options set on that context; otherwise, the behavior is undefined. No options are enabled on the default
context.

SHMEM_CTX_SERIALIZED	The given context is shareable; however, it will not be used by multiple threads concurrently. When the *SHMEM_CTX_SERIALIZED* option is set, the user must ensure that operations involving the given context are serialized by the application.
SHMEM_CTX_PRIVATE	The given context will be used only by the thread that created it.
SHMEM_CTX_NOSTORE	Quiet and fence operations performed on the given context are not required to enforce completion and ordering of memory store operations. When ordering of store operations is needed, the application must perform a synchronization operation on a context without the *SHMEM_CTX_NOSTORE* option enabled.

Return Values

Zero on success and nonzero otherwise.

Notes

None.

10.5.2 SHMEM_TEAM_CREATE_CTX

Create a communication context from a team.

SYNOPSIS

C/C++:
```
int shmem_team_create_ctx(shmem_team_t team, long options, shmem_ctx_t *ctx);
```

DESCRIPTION

Arguments

IN	*team*	A handle to the specified PE team.
IN	*options*	The set of options requested for the given context. Multiple options may be requested by combining them with a bitwise OR operation; otherwise, *0* can be given if no options are requested.
OUT	*ctx*	A handle to the newly created context.

API description

The *shmem_team_create_ctx* routine creates a new communication context and returns its handle through
the *ctx* argument. This context is created from the team specified by the *team* argument.

In addition to the team, the *shmem_team_create_ctx* routine accepts the same arguments and provides all the same return conditions as the *shmem_ctx_create* routine.

The *shmem_team_create_ctx* routine may be called any number of times to create multiple simultaneously existing contexts for the team. Programs should request the total number of simultaneous contexts to be created from the team during team creation. See Section 10.4.3 for more information on how to request contexts during team creation.

A call to *shmem_team_create_ctx* on a team may fail, regardless of the configuration request for contexts, if the implementation is unable to create a context at the time when *shmem_team_create_ctx* is called.

All explicitly created resources associated with a team must be destroyed before the *shmem_team_destroy* routine is called. If a context returned from *shmem_team_create_ctx* is not explicitly destroyed before the team is destroyed, behavior is undefined.

All OpenSHMEM routines that operate on this context will do so with respect to the associated PE team. That is, all point-to-point routines operating on this context will use team-relative PE numbering.

Return Values

Zero on success and nonzero otherwise.

Notes

None.

EXAMPLES

See example in Section 10.5.4

10.5.3 SHMEM_CTX_DESTROY

Destroy a locally created communication context.

SYNOPSIS

C/C++:
```
void shmem_ctx_destroy(shmem_ctx_t ctx);
```

DESCRIPTION

Arguments

IN   *ctx*   Handle to the context that will be destroyed.

API description

shmem_ctx_destroy destroys a context that was created by a call to *shmem_ctx_create* or *shmem_team_create_ctx*. It is the user's responsibility to ensure that the context is not used after it has been destroyed, for example when the destroyed context is used by multiple threads. This function performs an implicit quiet operation on the given context before it is freed. If *ctx* has the value *SHMEM_CTX_INVALID*, no operation is performed.

Return Values

None.

Notes

~~It is invalid to pass *SHMEM_CTX_DEFAULT* to this routine.~~

Destroying a context makes it impossible for the user to complete communication operations that are pending on that context. This includes nonblocking communication operations, whose local buffers are only returned to the user after the operations have been completed. An implicit quiet is performed when freeing a context to avoid this ambiguity.

A context with the *SHMEM_CTX_PRIVATE* option enabled must be destroyed by the thread that created it.

EXAMPLES

The following example demonstrates the use of contexts in a multithreaded *C11* program that uses OpenMP for threading. This example shows the shared counter load balancing method and illustrates the use of contexts for thread isolation.

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

long pwrk[SHMEM_REDUCE_MIN_WRKDATA_SIZE];
long psync[SHMEM_REDUCE_SYNC_SIZE];

long task_cntr  = 0; /* Next task counter */
long tasks_done = 0; /* Tasks done by this PE */
long total_done = 0; /* Total tasks done by all PEs */

int main(void) {
    int tl, i;
    long ntasks = 1024;  /* Total tasks per PE */

    for (i = 0; i < SHMEM_REDUCE_SYNC_SIZE; i++)
        psync[i] = SHMEM_SYNC_VALUE;

    shmem_init_thread(SHMEM_THREAD_MULTIPLE, &tl);
    if (tl != SHMEM_THREAD_MULTIPLE) shmem_global_exit(1);

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

#pragma omp parallel reduction (+:tasks_done)
    {
        shmem_ctx_t ctx;
        int task_pe = me, pes_done = 0;
        int ret = shmem_ctx_create(SHMEM_CTX_PRIVATE, &ctx);

        if (ret != 0) {
            printf("%d: Error creating context (%d)\n", me, ret);
            shmem_global_exit(2);
        }

        /* Process tasks on all PEs, starting with the local PE.  After
         * all tasks on a PE are completed, help the next PE. */
        while (pes_done < npes) {
            long task = shmem_atomic_fetch_inc(ctx, &task_cntr, task_pe);
            while (task < ntasks) {
                /* Perform task (task_pe, task) */
                tasks_done++;
                task = shmem_atomic_fetch_inc(ctx, &task_cntr, task_pe);
            }
            pes_done++;
            task_pe = (task_pe + 1) % npes;
        }

        shmem_ctx_destroy(ctx);
    }
```

```
        shmem_long_sum_to_all(&total_done, &tasks_done, 1, 0, 0, npes, pwrk, psync);

        int result = (total_done != ntasks * npes);
        shmem_finalize();
        return result;
    }
```

The following example demonstrates the use of contexts in a single-threaded *C11* program that performs a summation reduction where the data contained in the *in_buf* arrays on all PEs is reduced into the *out_buf* arrays on all PEs. The buffers are divided into segments and processing of the segments is pipelined. Contexts are used to overlap an all-to-all exchange of data for segment *p* with the local reduction of segment *p-1*.

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

    #define LEN  8192 /* Full buffer length */
    #define PLEN 512  /* Length of each pipeline stage */

    int in_buf[LEN], out_buf[LEN];

    int main(void) {
        int i, j, *pbuf[2];
        shmem_ctx_t ctx[2];

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

        pbuf[0] = shmem_malloc(PLEN * npes * sizeof(int));
        pbuf[1] = shmem_malloc(PLEN * npes * sizeof(int));

        int ret_0 = shmem_ctx_create(0, &ctx[0]);
        int ret_1 = shmem_ctx_create(0, &ctx[1]);
        if (ret_0 || ret_1) shmem_global_exit(1);

        for (i = 0; i < LEN; i++) {
            in_buf[i] = me; out_buf[i] = 0;
        }

        int p_idx = 0, p = 0; /* Index of ctx and pbuf (p_idx) for current pipeline stage (p) */
        for (i = 1; i <= npes; i++)
            shmem_put_nbi(ctx[p_idx], &pbuf[p_idx][PLEN*me], &in_buf[PLEN*p],
                          PLEN, (me+i) % npes);

        /* Issue communication for pipeline stage p, then accumulate results for stage p-1 */
        for (p = 1; p < LEN/PLEN; p++) {
            p_idx ^= 1;
            for (i = 1; i <= npes; i++)
                shmem_put_nbi(ctx[p_idx], &pbuf[p_idx][PLEN*me], &in_buf[PLEN*p],
                              PLEN, (me+i) % npes);

            shmem_ctx_quiet(ctx[p_idx^1]);
            shmem_sync_all();
            for (i = 0; i < npes; i++)
                for (j = 0; j < PLEN; j++)
                    out_buf[PLEN*(p-1)+j] += pbuf[p_idx^1][PLEN*i+j];
        }

        shmem_ctx_quiet(ctx[p_idx]);
        shmem_sync_all();
        for (i = 0; i < npes; i++)
            for (j = 0; j < PLEN; j++)
                out_buf[PLEN*(p-1)+j] += pbuf[p_idx][PLEN*i+j];

        shmem_finalize();
        return 0;
```

```
    }
```

The following example demonstrates the use of *SHMEM_CTX_INVALID* in a *C11* program that uses thread-local storage to provide each thread an implicit context handle via a "library" put routine without explicit management of the context handle from "user" code.

```c
#include <stddef.h>
#include <shmem.h>
#include <omp.h>

_Thread_local shmem_ctx_t thread_ctx = SHMEM_CTX_INVALID;

void lib_thread_register(void) {
  if (thread_ctx == SHMEM_CTX_INVALID)
    if (shmem_ctx_create(SHMEM_CTX_PRIVATE, &thread_ctx) &&
        shmem_ctx_create(              0, &thread_ctx))
      thread_ctx = SHMEM_CTX_DEFAULT;
}

void lib_thread_unregister(void) {
  if (thread_ctx != SHMEM_CTX_DEFAULT) {
    shmem_ctx_destroy(thread_ctx);
    thread_ctx = SHMEM_CTX_INVALID;
  }
}

void lib_thread_putmem(void *dst, const void *src, size_t nbytes, int pe) {
  shmem_ctx_putmem(thread_ctx, dst, src, nbytes, pe);
}

int main() {
  int provided;
  if (shmem_init_thread(SHMEM_THREAD_MULTIPLE, &provided))
    return 1;
  if (provided != SHMEM_THREAD_MULTIPLE)
    shmem_global_exit(2);

  const int my_pe = shmem_my_pe();
  const int n_pes = shmem_n_pes();
  const int count = 1 << 15;

  int *src_bufs[n_pes];
  int *dst_bufs[n_pes];
  for (int i = 0; i < n_pes; i++) {
    src_bufs[i] = shmem_calloc(count, sizeof(*src_bufs[i]));
    if (src_bufs[i] == NULL)
      shmem_global_exit(3);
    dst_bufs[i] = shmem_calloc(count, sizeof(*dst_bufs[i]));
    if (dst_bufs[i] == NULL)
      shmem_global_exit(4);
  }

#pragma omp parallel
  {
    int my_thrd = omp_get_thread_num();
#pragma omp for
    for (int i = 0; i < n_pes; i++)
      for (int j = 0; j < count; j++)
        src_bufs[i][j] = (my_pe << 10) + my_thrd;

    lib_thread_register();

#pragma omp for
    for (int i = 0; i < n_pes; i++)
      lib_thread_putmem(dst_bufs[my_pe], src_bufs[i],
                        count * sizeof(*src_bufs[i]), i);

    lib_thread_unregister();
```

```
    }

    shmem_finalize();
    return 0;
}
```

10.5.4   SHMEM_CTX_GET_TEAM

Retrieve the team associated with the communication context.

SYNOPSIS

  C/C++:
  int shmem_ctx_get_team(**shmem_ctx_t** ctx, **shmem_team_t** *team);

DESCRIPTION

  Arguments
      IN   *ctx*   A handle to a communication context.
      OUT   *team*   A pointer to a handle to the associated PE team.

  API description

      The *shmem_ctx_get_team* routine returns a handle to the team associated with the specified communication
      context *ctx*. The team handle is returned through the pointer argument *team*.
      If *ctx* is the default context or one created by a call to *shmem_ctx_create*, the returned team is the default
      team.
      If *ctx* is an invalid context, the behavior is undefined.
      If *team* is a null pointer, a value of *-1* is returned.

  Return Values
      Zero on success; otherwise, nonzero.

  Notes
      None.

EXAMPLES

      The following example demonstrates the use of contexts for multiple teams in a *C11* program. This example
      shows contexts being used to communicate within a team using team PE numbers, and across teams using
      translated PE numbers.

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

int isum, ival;

int my_ctx_translate_pe(shmem_ctx_t src_ctx, int src_pe, shmem_ctx_t dest_ctx)
{
    if (src_ctx == SHMEM_CTX_INVALID) {
```

```
      return -1;
    }                                                                          2
    if (dest_ctx == SHMEM_CTX_INVALID) {                                       3
      return -1;
    }                                                                          4

    shmem_team_t src_team, dest_team;                                          5
    shmem_ctx_get_team(src_ctx, &src_team);                                    6
    shmem_ctx_get_team(dest_ctx, &dest_team);
    return shmem_team_translate(src_team, src_pe, dest_pe);                     7
}                                                                              8

                                                                               9
shmem_ctx_t my_team_create_ctx(shmem_team_t team) {
    if (team == SHMEM_TEAM_INVALID) {                                          10
      return SHMEM_CTX_INVALID;                                                11
    }
                                                                               12
    shmem_ctx_t ctx;                                                           13
    if (shmem_team_create_ctx(team, 0, &ctx) != 0) {                           14
      fprintf (stderr, "Failed to create context for PE team\n");
      return SHMEM_CTX_INVALID;                                                15
    }                                                                          16
    return ctx;                                                                17
}
                                                                               18
void my_send_to_neighbor(shmem_ctx_t ctx, int *val)                            19
{
    if (ctx == SHMEM_CTX_INVALID) {                                            20
      fprintf (stderr, "Send to neighbor fail due to invalid context\n");
      return;                                                                  21
    }                                                                          22

                                                                               23
    shmem_team_t team;
    shmem_ctx_get_team(ctx, &team);                                            24
    int pe = shmem_team_my_pe(team);                                           25
    int npes = shmem_team_n_pes(team);
    int rpe = (pe + 1) % npes;                                                 26

                                                                               27
    // put my pe number in the buffer on my right hand neighbor
    shmem_ctx_int_put(ctx, val, &pe, 1, rpe);                                  28
}                                                                              29

                                                                               30

                                                                               31
int main()
{                                                                              32
    shmem_init();                                                              33

                                                                               34
    int npes = shmem_n_pes();
    isum = 0;                                                                  35

                                                                               36
    shmem_team_t team_2s, team_3s;
    shmem_ctx_t ctx_2s, ctx_3s;                                               37
    shmem_team_config_t conf;
    conf.num_contexts = 1;                                                     38
    long cmask = SHMEM_TEAM_NUM_CONTEXTS;                                      39

                                                                               40
    // Create team with PEs numbered 0, 2, 4, ...
    shmem_team_spit_strided(SHMEM_TEAM_WORLD, 0, 2, npes / 2, &conf, cmask, &team_2s);   41
    // Sync between splits from same parent team into teams with overlapping membership
    shmem_team_sync(SHMEM_TEAM_WORLD);                                         42
    // Create team with PEs numbered 0, 3, 6, ...                             43
    shmem_team_split_strided(SHMEM_TEAM_WORLD, 0, 3, npes / 3, &conf, cmask, &team_3s);
                                                                               44
    ctx_2s = my_team_create_ctx(team_2s);                                     45
    ctx_3s = my_team_create_ctx(team_3s);                                     46

                                                                               47
    // Send some values using the two team contexts contexts                  48
```

```
my_send_to_neighbor(ctx_2s, &ival2);
my_send_to_neighbor(ctx_3s, &ival3);

// Quiet all contexts and synchronize all PEs to complete the data transfers
shmem_ctx_quiet(ctx_2s);
shmem_ctx_quiet(ctx_3s);
shmem_team_sync(SHMEM_TEAM_WORLD);

// We will add up some results on pe 4 of team_3s using ctx_2s
if ((team_3s != SHMEM_TEAM_INVALID) && (team_2s != SHMEM_TEAM_INVALID)) {
  int _pe4_of_3s_in_2s = my_ctx_translate_pe(ctx_3s, 4, ctx_2s);

  if (_pe4_of_3s_in_2s < 0) {
    fprintf (stderr, "Fail to translate pe 4 from 3s context to 2s context\n");
  }
  else {
    // Add up the results on pe 4 of the 3s team, using the 2s team context
    shmem_ctx_int_atomic_add(ctx_2s, &isum, ival2 + ival3, _pe4_of_3s_in_2s);
  }
}

// Quiet the context and synchronize PEs to complete the operation
shmem_ctx_quiet(ctx_2s);
shmem_team_sync(SHMEM_TEAM_WORLD);

if (shmem_team_my_pe(team_3s) == 4) {
  printf ("The total value on PE 4 of the 3s team is %d\n", isum);
}

// Destroy contexts before teams
shmem_ctx_destroy(ctx_2s);
shmem_team_destroy(team_2s);

shmem_ctx_destroy(ctx_3s);
shmem_team_destroy(team_3s);

shmem_finalize();
}
```

10.6   Remote Memory Access Routines

The RMA routines described in this section can be used to perform reads from and writes to symmetric data objects. These operations are one-sided, meaning that the PE invoking an operation provides all communication parameters and the targeted PE is passive. A characteristic of one-sided communication is that it decouples communication from synchronization. One-sided communication mechanisms transfer data; however, they do not synchronize the sender of the data with the receiver of the data.

OpenSHMEM RMA routines are performed on symmetric data objects. The initiator PE of a call is designated as the *origin* PE and the PE targeted by an operation is designated as the *destination* PE. The *source* and *dest* designators refer to the data objects that an operation reads from and writes to. In the case of the remote update routine, *Put*, the origin PE provides the *source* data object and the destination PE provides the *dest* data object. In the case of the remote read routine, *Get*, the origin PE provides the *dest* data object and the destination PE provides the *source* data object.

The destination PE is specified as an integer representing the PE number. This PE number is relative to the Open-SHMEM team associated with the communication context being using for the operation. If no context is passed to the routine, then the PE number is relative to the default team, and is the global PE number. If the PE number passed to the routine is invalid, being negative or greater than or equal to the size of the OpenSHMEM team, then routine behavior is undefined.

Where appropriate compiler support is available, OpenSHMEM provides type-generic one-sided communication interfaces via *C11* generic selection (*C11* §6.5.1.1[5]) for block, scalar, and block-strided put and get communication.

---

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

Such type-generic routines are supported for the "standard RMA types" listed in Table 3.

The standard RMA types include the exact-width integer types defined in *stdint.h* by *C99*[6] §7.18.1.1 and *C11* §7.20.1.1. When the *C* translation environment does not provide exact-width integer types with *stdint.h*, an OpenSHMEM imple- memementation is not required to provide support for these types.

TYPE	TYPENAME
float	float
double	double
long double	longdouble
char	char
signed char	schar
short	short
int	int
long	long
long long	longlong
unsigned char	uchar
unsigned short	ushort
unsigned int	uint
unsigned long	ulong
unsigned long long	ulonglong
int8_t	int8
int16_t	int16
int32_t	int32
int64_t	int64
uint8_t	uint8
uint16_t	uint16
uint32_t	uint32
uint64_t	uint64
size_t	size
ptrdiff_t	ptrdiff

Table 3: Standard RMA Types and Names

10.6.1   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);
> void shmem_put(shmem_ctx_t ctx, TYPE *dest, const TYPE *source, size_t nelems, int pe);
> ```
> where *TYPE* is one of the standard RMA types specified by Table 3.
>
>   **C/C++:**
> ```
> void shmem_<TYPENAME>_put(TYPE *dest, const TYPE *source, size_t nelems, int pe);
> void shmem_ctx_<TYPENAME>_put(shmem_ctx_t ctx, 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 3.

---

[6]Formally, the *C99* specification is ISO/IEC 9899:1999(E).

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

— deprecation start ———————————————————————————————————————

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)
```

—— deprecation end —

DESCRIPTION

> **Arguments**
>
> | | | | |
> |---|---|---|---|
> | **IN** | *ctx* | A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context. | |
> | **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*. When 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. When 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. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.
>
> 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
When 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))*. As of OpenSHMEM 1.2, 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 *C11* programs:

```c
#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();
    int me = shmem_my_pe();
    if (me == 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", me, dest[0]);
    shmem_finalize();
    return 0;
}
```

10.6.2 SHMEM_P

Copies one data item to a remote PE.

SYNOPSIS

C11:
```c
void shmem_p(TYPE *dest, TYPE value, int pe);
void shmem_p(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
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where *TYPE* is one of the standard RMA types specified by Table 3.

C/C++:

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

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

DESCRIPTION

Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
OUT	*dest*	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 *dest* 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.

If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

Return Values
None.

Notes
None.

EXAMPLES

The following example uses *shmem_p* in a *C11* program.

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

int main(void)
{
    const double e = 2.71828182;
    const double epsilon = 0.00000001;
    static double f = 3.1415927;
    shmem_init();
    int me = shmem_my_pe();
    if (me == 0)
        shmem_p(&f, e, 1);
    shmem_barrier_all();
    if (me == 1)
        printf("%s\n", (fabs(f - e) < epsilon) ? "OK" : "FAIL");
    shmem_finalize();
    return 0;
}
```

10.6.3 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);
void shmem_iput(shmem_ctx_t ctx, 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 3.

C/C++:
```
void shmem_<TYPENAME>_iput(TYPE *dest, const TYPE *source, ptrdiff_t dst, ptrdiff_t sst,
    size_t nelems, int pe);
void shmem_ctx_<TYPENAME>_iput(shmem_ctx_t ctx, 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 3.
```
void shmem_iput<SIZE>(void *dest, const void *source, ptrdiff_t dst, ptrdiff_t sst, size_t
    nelems, int pe);
void shmem_ctx_iput<SIZE>(shmem_ctx_t ctx, 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*.

— deprecation start —————————————————————————————————————

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)
```
————————————————————————————————————— deprecation end —

DESCRIPTION

Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
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*. When 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*. When 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*. When 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. When 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. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

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
When 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 *C11* programs.

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

int main(void)
```

```
{                                                                                              1
   short source[10] = { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };                                      2
   static short dest[10];                                                                       3
   shmem_init();
   int me = shmem_my_pe();                                                                      4
   if (me == 0) /* put 5 elements into dest on PE 1 */                                          5
      shmem_iput(dest, source, 1, 2, 5, 1);
   shmem_barrier_all(); /* sync sender and receiver */                                          6
   if (me == 1) {                                                                               7
      printf("dest on PE %d is %hd %hd %hd %hd %hd\n", me,
         dest[0], dest[1], dest[2], dest[3], dest[4]);                                          8
   }                                                                                            9
   shmem_finalize();
   return 0;                                                                                    10
}                                                                                              11
```

10.6.4 SHMEM_GET

Copies data from a specified PE.

SYNOPSIS

C11:
```
void shmem_get(TYPE *dest, const TYPE *source, size_t nelems, int pe);
void shmem_get(shmem_ctx_t ctx, TYPE *dest, const TYPE *source, size_t nelems, int pe);
```

where *TYPE* is one of the standard RMA types specified by Table 3.

C/C++:
```
void shmem_<TYPENAME>_get(TYPE *dest, const TYPE *source, size_t nelems, int pe);
void shmem_ctx_<TYPENAME>_get(shmem_ctx_t ctx, 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 3.
```
void shmem_get<SIZE>(void *dest, const void *source, size_t  nelems, int pe);
void shmem_ctx_get<SIZE>(shmem_ctx_t ctx, 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);
void shmem_ctx_getmem(shmem_ctx_t ctx, void *dest, const void *source, size_t nelems, int
   pe);
```

— deprecation start ———

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_GET64(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)
```

——— deprecation end —

DESCRIPTION

Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
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*. When 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. When 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. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

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. When 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
```

10.6.5 SHMEM_G

Copies one data item from a remote PE

SYNOPSIS

C11:
```
TYPE shmem_g(const TYPE *source, int pe);
TYPE shmem_g(shmem_ctx_t ctx, const TYPE *source, int pe);
```
where *TYPE* is one of the standard RMA types specified by Table 3.

C/C++:
```
TYPE shmem_<TYPENAME>_g(const TYPE *source, int pe);
TYPE shmem_ctx_<TYPENAME>_g(shmem_ctx_t ctx, const TYPE *source, int pe);
```
where *TYPE* is one of the standard RMA types and has a corresponding *TYPENAME* specified by Table 3.

DESCRIPTION

Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
IN	*source*	The remotely accessible array element or scalar data object.
IN	*pe*	The number of the remote PE on which *source* resides.

API description

These routines provide a very low latency get capability for single elements of most basic types. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

Return Values
    Returns a single element of type specified in the synopsis.

Notes
    None.

EXAMPLES

The following *shmem_g* example is for *C11* programs:

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

int main(void)
{
    long y = -1;
    static long x = 10101;
    shmem_init();
    int me = shmem_my_pe();
    int npes = shmem_n_pes();
    if (me == 0)
        y = shmem_g(&x, npes-1);
    printf("%d: y = %ld\n", me, y);
    shmem_finalize();
    return 0;
}
```


10.6.6 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);
void shmem_iget(shmem_ctx_t ctx, 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 3.

C/C++:
```
void shmem_<TYPENAME>_iget(TYPE *dest, const TYPE *source, ptrdiff_t dst, ptrdiff_t sst,
    size_t nelems, int pe);
void shmem_ctx_<TYPENAME>_iget(shmem_ctx_t ctx, 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 3.
```
void shmem_iget<SIZE>(void *dest, const void *source, ptrdiff_t dst, ptrdiff_t sst, size_t
    nelems, int pe);
void shmem_ctx_iget<SIZE>(shmem_ctx_t ctx, 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*.

—— deprecation start ——
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)                              1
CALL SHMEM_IGET8(dest, source, dst, sst, nelems, pe)                              2
CALL SHMEM_IGET32(dest, source, dst, sst, nelems, pe)                             3
CALL SHMEM_IGET64(dest, source, dst, sst, nelems, pe)                             4
CALL SHMEM_IGET128(dest, source, dst, sst, nelems, pe)                            5
CALL SHMEM_INTEGER_IGET(dest, source, dst, sst, nelems, pe)                       6
CALL SHMEM_LOGICAL_IGET(dest, source, dst, sst, nelems, pe)                       7
CALL SHMEM_REAL_IGET(dest, source, dst, sst, nelems, pe)                          8
```
——— deprecation end —   9

                                                                                 10

DESCRIPTION   11

                                                                                 12

Arguments   13

IN   *ctx*   A context handle specifying the context on which to perform the oper-   14
                                 ation. When this argument is not provided, the operation is performed   15
                                 on the default context.   16

OUT   *dest*   Array to be updated on the local PE.   17

IN   *source*   Array containing the data to be copied on the remote PE.   18

IN   *dst*   The stride between consecutive elements of the *dest* array. The stride 19
                                 is scaled by the element size of the *dest* array. A value of *1* indicates 20
                                 contiguous data. *dst* must be of type *ptrdiff_t*. When using *Fortran*, it 20
                                 must be a default integer value.   21

IN   *sst*   The stride between consecutive elements of the *source* array. The stride 22
                                 is scaled by the element size of the *source* array. A value of *1* indicates 23
                                 contiguous data. *sst* must be of type *ptrdiff_t*. When using *Fortran*, it 24
                                 must be a default integer value.   25

IN   *nelems*   Number of elements in the *dest* and *source* arrays. *nelems* must be of 26
                                 type *size_t* for *C*. When using *Fortran*, it must be a constant, variable, 27
                                 or array element of default integer type.   27

IN   *pe*   PE number of the remote PE. *pe* must be of type integer. When us-   28
                                 ing *Fortran*, it must be a constant, variable, or array element of default 29
                                 integer type.   30

                                                                                 31

API description   32

                                                                                 33

The *iget* routines provide a method for copying strided data elements from a symmetric array from a   34
specified remote PE to strided locations on a local array. The routines return when the data has been copied 35
into the local *dest* array. If the context handle *ctx* does not correspond to a valid context, the behavior is 36
undefined.   37

                                                                                 38

                                                                                 39

The *dest* and *source* data objects must conform to typing constraints, which are as follows: 40

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
> When 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.

```fortran
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
```

10.7   Non-blocking Remote Memory Access Routines

10.7.1   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:
```c
void shmem_put_nbi(TYPE *dest, const TYPE *source, size_t nelems, int pe);
void shmem_put_nbi(shmem_ctx_t ctx, TYPE *dest, const TYPE *source, size_t nelems, int pe);
```

where *TYPE* is one of the standard RMA types specified by Table 3.

C/C++:
```c
void shmem_<TYPENAME>_put_nbi(TYPE *dest, const TYPE *source, size_t nelems, int pe);
void shmem_ctx_<TYPENAME>_put_nbi(shmem_ctx_t ctx, 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 3.

```c
void shmem_put<SIZE>_nbi(void *dest, const void *source, size_t nelems, int pe);
void shmem_ctx_put<SIZE>_nbi(shmem_ctx_t ctx, 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);           1
void shmem_ctx_putmem_nbi(shmem_ctx_t ctx, void *dest, const void *source, size_t nelems,  2
    int pe);                                                                              3
```
—— deprecation start ——   4
FORTRAN: 5
```
CALL SHMEM_CHARACTER_PUT_NBI(dest, source, nelems, pe)                                    6
CALL SHMEM_COMPLEX_PUT_NBI(dest, source, nelems, pe)                                      7
CALL SHMEM_DOUBLE_PUT_NBI(dest, source, nelems, pe)                                       8
CALL SHMEM_INTEGER_PUT_NBI(dest, source, nelems, pe)                                      9
CALL SHMEM_LOGICAL_PUT_NBI(dest, source, nelems, pe)                                      10
CALL SHMEM_PUT4_NBI(dest, source, nelems, pe)                                             11
CALL SHMEM_PUT8_NBI(dest, source, nelems, pe)                                             12
CALL SHMEM_PUT32_NBI(dest, source, nelems, pe)                                            13
CALL SHMEM_PUT64_NBI(dest, source, nelems, pe)                                            14
CALL SHMEM_PUT128_NBI(dest, source, nelems, pe)                                           15
CALL SHMEM_PUTMEM_NBI(dest, source, nelems, pe)                                           16
CALL SHMEM_REAL_PUT_NBI(dest, source, nelems, pe)                                         17
```
—— deprecation end ——   17
                                                                                          18
                                                                                          19
DESCRIPTION   20
                                                                                          21
Arguments   22
    IN   *ctx*   A context handle specifying the context on which to perform the oper-   23
        ation. When this argument is not provided, the operation is performed   24
        on the default context.
    OUT   *dest*   Data object to be updated on the remote PE. This data object must be   25
        remotely accessible.   26
    IN   *source*   Data object containing the data to be copied.   27
    IN   *nelems*   Number of elements in the *dest* and *source* arrays. *nelems* must be of   28
        type *size_t* for *C*. When using *Fortran*, it must be a constant, variable,   29
        or array element of default integer type.   30
    IN   *pe*   PE number of the remote PE. *pe* must be of type integer. When us-   31
        ing *Fortran*, it must be a constant, variable, or array element of default   32
        integer type.   33
                                                                                          34
API description   35
                                                                                          36
The routines return after posting the operation. The operation is considered complete after a subsequent   37
call to *shmem_quiet*. At the completion of *shmem_quiet*, the data has been copied into the *dest* array on   38
the destination PE. The delivery of data words into the data object on the destination PE may occur in any   39
order. Furthermore, two successive put routines may deliver data out of order unless a call to *shmem_fence*   40
is introduced between the two calls. If the context handle *ctx* does not correspond to a valid context, the   41
behavior is undefined.   42
                                                                                          43
                                                                                          44
The *dest* and *source* data objects must conform to certain typing constraints, which are as follows: 45
                                                                                          46

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.

10.7.2 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);
> void shmem_get_nbi(shmem_ctx_t ctx, TYPE *dest, const TYPE *source, size_t nelems, int pe);
> ```
> where *TYPE* is one of the standard RMA types specified by Table 3.
>
> **C/C++:**
> ```
> void shmem_<TYPENAME>_get_nbi(TYPE *dest, const TYPE *source, size_t nelems, int pe);
> void shmem_ctx_<TYPENAME>_get_nbi(shmem_ctx_t ctx, 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 3.
> ```
> void shmem_get<SIZE>_nbi(void *dest, const void *source, size_t  nelems, int pe);
> void shmem_ctx_get<SIZE>_nbi(shmem_ctx_t ctx, 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);
> void shmem_ctx_getmem_nbi(shmem_ctx_t ctx, void *dest, const void *source, size_t nelems,
>     int pe);
> ```
> —— deprecation start ——
> **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)                                    1
CALL SHMEM_GET4_NBI(dest, source, nelems, pe)                                          2
CALL SHMEM_GET8_NBI(dest, source, nelems, pe)                                          3
CALL SHMEM_GET32_NBI(dest, source, nelems, pe)                                         4
CALL SHMEM_GET64_NBI(dest, source, nelems, pe)                                         5
CALL SHMEM_GET128_NBI(dest, source, nelems, pe)                                        6
CALL SHMEM_GETMEM_NBI(dest, source, nelems, pe)                                        7
CALL SHMEM_INTEGER_GET_NBI(dest, source, nelems, pe)                                   8
CALL SHMEM_LOGICAL_GET_NBI(dest, source, nelems, pe)                                   9
CALL SHMEM_REAL_GET_NBI(dest, source, nelems, pe)                                     10
```

—— deprecation end —

DESCRIPTION

Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.	
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*. When 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. When 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. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

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. When 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))*.

10.8 Atomic Memory Operations

An AMO is a one-sided communication mechanism that combines memory read, update, or write operations with atomicity guarantees described in Section 3.1. Similar to the RMA routines, described in Section 10.6, the AMOs are performed only on symmetric objects. OpenSHMEM defines 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 from the target PE and delivered to the calling PE. The data type of the returned value is the same as the type of the remote data object.

    The fetching routines include: *shmem_atomic_{fetch, compare_swap, swap}* and *shmem_atomic_fetch_{inc, add, and, or, xor}*.

- The *non-fetching* routines update the remote data object in a single atomic operation. A call to a non-fetching atomic routine issues the atomic operation and may return before the operation executes on the target PE. The *shmem_quiet*, *shmem_barrier*, or *shmem_barrier_all* routines can be used to force completion for these non-fetching atomic routines.

    The non-fetching routines include: *shmem_atomic_{set, inc, add, and, or, xor}*.

Where appropriate compiler support is available, OpenSHMEM provides type-generic AMO interfaces via *C11* generic selection. The type-generic support for the AMO routines is as follows:

- *shmem_atomic_{compare_swap, fetch_inc, inc, fetch_add, add}* support the "standard AMO types" listed in Table 4,

- *shmem_atomic_{fetch, set, swap}* support the "extended AMO types" listed in Table 5, and

- *shmem_atomic_{fetch_and, and, fetch_or, or, fetch_xor, xor}* support the "bitwise AMO types" listed in Table 6.

The standard, extended, and bitwise AMO types include some of the exact-width integer types defined in *stdint.h* by *C99* §7.18.1.1 and *C11* §7.20.1.1. When the *C* translation environment does not provide exact-width integer types with *stdint.h*, an OpenSHMEM implemementation is not required to provide support for these types.

TYPE	TYPENAME
int	int
long	long
long long	longlong
unsigned int	uint
unsigned long	ulong
unsigned long long	ulonglong
int32_t	int32
int64_t	int64
uint32_t	uint32
uint64_t	uint64
size_t	size
ptrdiff_t	ptrdiff

Table 4: Standard AMO Types and Names

TYPE	TYPENAME
float	float
double	double
int	int
long	long
long long	longlong
unsigned int	uint
unsigned long	ulong
unsigned long long	ulonglong
int32_t	int32
int64_t	int64
uint32_t	uint32
uint64_t	uint64
size_t	size
ptrdiff_t	ptrdiff

Table 5: Extended AMO Types and Names

10.8.1 SHMEM_ATOMIC_FETCH

Atomically fetches the value of a remote data object.

SYNOPSIS

C11:
```
TYPE shmem_atomic_fetch(const TYPE *source, int pe);
TYPE shmem_atomic_fetch(shmem_ctx_t ctx, const TYPE *source, int pe);
```

where *TYPE* is one of the extended AMO types specified by Table 5.

C/C++:
```
TYPE shmem_<TYPENAME>_atomic_fetch(const TYPE *source, int pe);
TYPE shmem_ctx_<TYPENAME>_atomic_fetch(shmem_ctx_t ctx, const TYPE *source, int pe);
```

where *TYPE* is one of the extended AMO types and has a corresponding *TYPENAME* specified by Table 5.

— deprecation start ———

C11:

TYPE	*TYPENAME*
unsigned int	uint
unsigned long	ulong
unsigned long long	ulonglong
int32_t	int32
int64_t	int64
uint32_t	uint32
uint64_t	uint64

Table 6: Bitwise AMO Types and Names

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

where *TYPE* is one of {*float*, *double*, *int*, *long*, *long long*}.

C/C++:
```
TYPE shmem_<TYPENAME>_fetch(const TYPE *source, int pe);
```

where *TYPE* is one of {*float*, *double*, *int*, *long*, *long long*} and has a corresponding *TYPENAME* specified by Table 5.

—— deprecation end —

— deprecation start ——

FORTRAN:
```
INTEGER pe
INTEGER*4 SHMEM_INT4_FETCH, ires_i4
ires\_i4 = SHMEM_INT4_FETCH(source, pe)
INTEGER*8 SHMEM_INT8_FETCH, ires_i8
ires\_i8 = SHMEM_INT8_FETCH(source, pe)
REAL*4 SHMEM_REAL4_FETCH, res_r4
res\_r4 = SHMEM_REAL4_FETCH(source, pe)
REAL*8 SHMEM_REAL8_FETCH, res_r8
res\_r8 = SHMEM_REAL8_FETCH(source, pe)
```
—— deprecation end —

DESCRIPTION

Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
IN	*source*	The remotely accessible data object to be fetched from the remote PE.
IN	*pe*	An integer that indicates the PE number from which *source* is to be fetched.

API description

shmem_atomic_fetch performs an atomic fetch operation. It returns the contents of the *source* as an atomic operation. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

Return Values

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

Notes

None.

10.8.2 SHMEM_ATOMIC_SET

Atomically sets the value of a remote data object.

SYNOPSIS

C11:
```
void shmem_atomic_set(TYPE *dest, TYPE value, int pe);
void shmem_atomic_set(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the extended AMO types specified by Table 5.

C/C++:
```
void shmem_<TYPENAME>_atomic_set(TYPE *dest, TYPE value, int pe);
void shmem_ctx_<TYPENAME>_atomic_set(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the extended AMO types and has a corresponding *TYPENAME* specified by Table 5.

—— deprecation start ——————————————————————————————

C11:
```
void shmem_set(TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of {*float*, *double*, *int*, *long*, *long long*}.

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

where *TYPE* is one of {*float*, *double*, *int*, *long*, *long long*} and has a corresponding *TYPENAME* specified by Table 5.

————————————————————————————————————— deprecation end —

—— deprecation start ——————————————————————————————
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)
```
————————————————————————————————————— deprecation end —

DESCRIPTION

Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
OUT	*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_atomic_set performs an atomic set operation. It writes the *value* into *dest* on *pe* as an atomic operation. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

Return Values
  None.

Notes
  None.

10.8.3   SHMEM_ATOMIC_COMPARE_SWAP

Performs an atomic conditional swap on a remote data object.

SYNOPSIS

  C11:
```
TYPE shmem_atomic_compare_swap(TYPE *dest, TYPE cond, TYPE value, int pe);
TYPE shmem_atomic_compare_swap(shmem_ctx_t ctx, TYPE *dest, TYPE cond, TYPE value, int pe);
```
  where *TYPE* is one of the standard AMO types specified by Table 4.

  C/C++:
```
TYPE shmem_<TYPENAME>_atomic_compare_swap(TYPE *dest, TYPE cond, TYPE value, int pe);
TYPE shmem_ctx_<TYPENAME>_atomic_compare_swap(shmem_ctx_t ctx, 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 4.

  —— deprecation start ——

  C11:
```
TYPE shmem_cswap(TYPE *dest, TYPE cond, TYPE value, int pe);
```
  where *TYPE* is one of {*int*, *long*, *long long*}.

  C/C++:
```
TYPE shmem_<TYPENAME>_cswap(TYPE *dest, TYPE cond, TYPE value, int pe);
```
  where *TYPE* is one of {*int*, *long*, *long long*} and has a corresponding *TYPENAME* specified by Table 4.

  ——— deprecation end ——

  —— deprecation start ——
  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

IN	*ctx*		A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
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. When 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. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

When using *Fortran*, *dest*, *cond*, and *value* must be of the following type:

Routine	Data type of *dest*, *cond*, 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;
```

```
        shmem_init();
        int me = shmem_my_pe();
        int oldval = shmem_atomic_compare_swap(&race_winner, -1, me, 0);
        if (oldval == -1) printf("PE %d was first\n", me);
        shmem_finalize();
        return 0;
}
```

10.8.4 SHMEM_ATOMIC_SWAP

Performs an atomic swap to a remote data object.

SYNOPSIS

> **C11:**
> ```
> TYPE shmem_atomic_swap(TYPE *dest, TYPE value, int pe);
> TYPE shmem_atomic_swap(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
> ```
> where *TYPE* is one of the extended AMO types specified by Table 5.
>
> **C/C++:**
> ```
> TYPE shmem_<TYPENAME>_atomic_swap(TYPE *dest, TYPE value, int pe);
> TYPE shmem_ctx_<TYPENAME>_atomic_swap(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
> ```
> where *TYPE* is one of the extended AMO types and has a corresponding *TYPENAME* specified by Table 5.
>
> —— deprecation start ——
> **C11:**
> ```
> TYPE shmem_swap(TYPE *dest, TYPE value, int pe);
> ```
> where *TYPE* is one of {*float*, *double*, *int*, *long*, *long long*}.
>
> **C/C++:**
> ```
> TYPE shmem_<TYPENAME>_swap(TYPE *dest, TYPE value, int pe);
> ```
> where *TYPE* is one of {*float*, *double*, *int*, *long*, *long long*} and has a corresponding *TYPENAME* specified by
> Table 5.
> ——— deprecation end ——
> —— deprecation start ——
> **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)
> ```
> ——— deprecation end ——

DESCRIPTION

> **Arguments**
>
> | | | |
> |---|---|---|
> | **IN** | *ctx* | A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context. |

OUT	*dest*	The remotely accessible integer data object to be updated on the remote PE. When 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. When using *Fortran*, it must be a default integer value.

API description

shmem_atomic_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 the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

When using *Fortran*, *dest* and *value* must be of the following type:

Routine	Data type of *dest* and *value*
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 swaps values between odd numbered PEs and their right (modulo) neighbor and outputs the result of swap.

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

int main(void)
{
  static long dest;
  shmem_init();
  int me = shmem_my_pe();
  int npes = shmem_n_pes();
  dest = me;
  shmem_barrier_all();
  long new_val = me;
  if (me & 1) {
    long swapped_val = shmem_atomic_swap(&dest, new_val, (me + 1) % npes);
    printf("%d: dest = %ld, swapped = %ld\n", me, dest, swapped_val);
  }
  shmem_finalize();
  return 0;
}
```

10.8.5 SHMEM_ATOMIC_FETCH_INC

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

SYNOPSIS

    C11:
```
TYPE shmem_atomic_fetch_inc(TYPE *dest, int pe);
TYPE shmem_atomic_fetch_inc(shmem_ctx_t ctx, TYPE *dest, int pe);
```
    where *TYPE* is one of the standard AMO types specified by Table 4.

    C/C++:
```
TYPE shmem_<TYPENAME>_atomic_fetch_inc(TYPE *dest, int pe);
TYPE shmem_ctx_<TYPENAME>_atomic_fetch_inc(shmem_ctx_t ctx, TYPE *dest, int pe);
```
    where *TYPE* is one of the standard AMO types and has a corresponding *TYPENAME* specified by Table 4.

— deprecation start ——

    C11:
```
TYPE shmem_finc(TYPE *dest, int pe);
```
    where *TYPE* is one of {*int*, *long*, *long long*}.

    C/C++:
```
TYPE shmem_<TYPENAME>_finc(TYPE *dest, int pe);
```
    where *TYPE* is one of {*int*, *long*, *long long*} and has a corresponding *TYPENAME* specified by Table 4.

——— deprecation end —

— deprecation start ——
    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)
```
——— deprecation end —

DESCRIPTION

    Arguments

        IN   *ctx*   A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.

        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   *pe*   An integer that indicates the PE number on which *dest* is to be updated. When 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 the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

When using *Fortran*, *dest* must be of the following type:

Routine	Data type of *dest*
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_atomic_fetch_inc* example is for *C11* programs:

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

int main(void)
{
   int old = -1;
   static int dst = 22;
   shmem_init();
   int me = shmem_my_pe();
   if (me == 0)
      old = shmem_atomic_fetch_inc(&dst, 1);
   shmem_barrier_all();
   printf("%d: old = %d, dst = %d\n", me, old, dst);
   shmem_finalize();
   return 0;
}
```

10.8.6 SHMEM_ATOMIC_INC

Performs an atomic increment operation on a remote data object.

SYNOPSIS

C11:
```c
void shmem_atomic_inc(TYPE *dest, int pe);
void shmem_atomic_inc(shmem_ctx_t ctx, TYPE *dest, int pe);
```
where *TYPE* is one of the standard AMO types specified by Table 4.

C/C++:
```c
void shmem_<TYPENAME>_atomic_inc(TYPE *dest, int pe);
void shmem_ctx_<TYPENAME>_atomic_inc(shmem_ctx_t ctx, TYPE *dest, int pe);
```
where *TYPE* is one of the standard AMO types and has a corresponding *TYPENAME* specified by Table 4.

—— deprecation start ——

C11:

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

where *TYPE* is one of {*int*, *long*, *long long*}.

C/C++:

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

where *TYPE* is one of {*int*, *long*, *long long*} and has a corresponding *TYPENAME* specified by Table 4.

—— deprecation end —

— deprecation start ——

FORTRAN:

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

—— deprecation end —

DESCRIPTION

    Arguments

IN	*ctx*		A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
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	*pe*		An integer that indicates the PE number on which *dest* is to be updated. When 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 the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

        When using *Fortran*, *dest* must be of the following type:

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

    Return Values
        None.

    Notes
        None.

EXAMPLES

The following *shmem_atomic_inc* example is for *C11* programs:

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

int main(void)
{
   static int dst = 74;
   shmem_init();
   int me = shmem_my_pe();
   if (me == 0)
      shmem_atomic_inc(&dst, 1);
   shmem_barrier_all();
   printf("%d: dst = %d\n", me, dst);
   shmem_finalize();
   return 0;
}
```

10.8.7 SHMEM_ATOMIC_FETCH_ADD

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

SYNOPSIS

C11:
```c
TYPE shmem_atomic_fetch_add(TYPE *dest, TYPE value, int pe);
TYPE shmem_atomic_fetch_add(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```
where *TYPE* is one of the standard AMO types specified by Table 4.

C/C++:
```c
TYPE shmem_<TYPENAME>_atomic_fetch_add(TYPE *dest, TYPE value, int pe);
TYPE shmem_ctx_<TYPENAME>_atomic_fetch_add(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```
where *TYPE* is one of the standard AMO types and has a corresponding *TYPENAME* specified by Table 4.

— deprecation start ———

C11:
```c
TYPE shmem_fadd(TYPE *dest, TYPE value, int pe);
```
where *TYPE* is one of {*int*, *long*, *long long*}.

C/C++:
```c
TYPE shmem_<TYPENAME>_fadd(TYPE *dest, TYPE value, int pe);
```
where *TYPE* is one of {*int*, *long*, *long long*} and has a corresponding *TYPENAME* specified by Table 4.

——— deprecation end —

— deprecation start ———
FORTRAN:
```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)
```
——— deprecation end —

DESCRIPTION

Arguments

IN	*ctx*		A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
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. When using *Fortran*, it must be a default integer value.

API description

shmem_atomic_fetch_add 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 the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

When using *Fortran*, *dest* and *value* must be of the following type:

Routine	Data type of *dest* and *value*
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_atomic_fetch_add* example is for *C11* programs:

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

int main(void)
{
   int old = -1;
   static int dst = 22;
   shmem_init();
   int me = shmem_my_pe();
   if (me == 1)
      old = shmem_atomic_fetch_add(&dst, 44, 0);
   shmem_barrier_all();
```

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

10.8.8   SHMEM_ATOMIC_ADD

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

SYNOPSIS

> **C11:**
> ```
> void shmem_atomic_add(TYPE *dest, TYPE value, int pe);
> void shmem_atomic_add(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
> ```
> where *TYPE* is one of the standard AMO types specified by Table 4.
>
> **C/C++:**
> ```
> void shmem_<TYPENAME>_atomic_add(TYPE *dest, TYPE value, int pe);
> void shmem_ctx_<TYPENAME>_atomic_add(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
> ```
> where *TYPE* is one of the standard AMO types and has a corresponding *TYPENAME* specified by Table 4.
>
> — deprecation start ——
> **C11:**
> ```
> void shmem_add(TYPE *dest, TYPE value, int pe);
> ```
> where *TYPE* is one of {*int*, *long*, *long long*}.
>
> **C/C++:**
> ```
> void shmem_<TYPENAME>_add(TYPE *dest, TYPE value, int pe);
> ```
> where *TYPE* is one of {*int*, *long*, *long long*} and has a corresponding *TYPENAME* specified by Table 4.
> ——— deprecation end —
>
> — deprecation start ——
> **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)
> ```
> ——— deprecation end —

DESCRIPTION

> **Arguments**
>
> | | | |
> |---|---|---|
> | **IN** | *ctx* | A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context. |
> | **OUT** | *dest* | The remotely accessible integer data object to be updated on the remote PE. When 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*. When using *C/C++*, the type of *value* should match that implied in the SYNOPSIS section. When 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. When using *Fortran*, it must be a default integer value. |

API description

The *shmem_atomic_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 the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

When using *Fortran*, *dest* and *value* must be of the following type:

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

Return Values
None.

Notes
None.

EXAMPLES

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

int main(void)
{
    static int dst = 22;
    shmem_init();
    int me = shmem_my_pe();
    if (me == 1)
        shmem_atomic_add(&dst, 44, 0);
    shmem_barrier_all();
    printf("%d: dst = %d\n", me, dst);
    shmem_finalize();
    return 0;
}
```

10.8.9   SHMEM_ATOMIC_FETCH_AND

Atomically perform a fetching bitwise AND operation on a remote data object.

SYNOPSIS

C11:
```
TYPE shmem_atomic_fetch_and(TYPE *dest, TYPE value, int pe);
TYPE shmem_atomic_fetch_and(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```
where *TYPE* is one of the bitwise AMO types specified by Table 6.

C/C++:
```
TYPE shmem_<TYPENAME>_atomic_fetch_and(TYPE *dest, TYPE value, int pe);
TYPE shmem_ctx_<TYPENAME>_atomic_fetch_and(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```
where *TYPE* is one of the bitwise AMO types and has a corresponding *TYPENAME* specified by Table 6.

DESCRIPTION

    Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
OUT	*dest*	A pointer to the remotely accessible data object to be updated.
IN	*value*	The operand to the bitwise AND operation.
IN	*pe*	An integer value for the PE on which *dest* is to be updated.

    API description

        shmem_atomic_fetch_and atomically performs a fetching bitwise AND on the remotely accessible data object pointed to by *dest* at PE *pe* with the operand *value*. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

    Return Values

        The value pointed to by *dest* on PE *pe* immediately before the operation is performed.

    Notes

        None.

10.8.10 SHMEM_ATOMIC_AND

Atomically perform a non-fetching bitwise AND operation on a remote data object.

SYNOPSIS

    C11:
```
void shmem_atomic_and(TYPE *dest, TYPE value, int pe);
void shmem_atomic_and(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```
    where *TYPE* is one of the bitwise AMO types specified by Table 6.

    C/C++:
```
void shmem_<TYPENAME>_atomic_and(TYPE *dest, TYPE value, int pe);
void shmem_ctx_<TYPENAME>_atomic_and(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```
    where *TYPE* is one of the bitwise AMO types and has a corresponding *TYPENAME* specified by Table 6.

DESCRIPTION

    Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
OUT	*dest*	A pointer to the remotely accessible data object to be updated.
IN	*value*	The operand to the bitwise AND operation.
IN	*pe*	An integer value for the PE on which *dest* is to be updated.

API description

shmem_atomic_and atomically performs a non-fetching bitwise AND on the remotely accessible data object pointed to by *dest* at PE *pe* with the operand *value*. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

Return Values
None.

Notes
None.

10.8.11 SHMEM_ATOMIC_FETCH_OR

Atomically perform a fetching bitwise OR operation on a remote data object.

SYNOPSIS

C11:
```
TYPE shmem_atomic_fetch_or(TYPE *dest, TYPE value, int pe);
TYPE shmem_atomic_fetch_or(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```
where *TYPE* is one of the bitwise AMO types specified by Table 6.

C/C++:
```
TYPE shmem_<TYPENAME>_atomic_fetch_or(TYPE *dest, TYPE value, int pe);
TYPE shmem_ctx_<TYPENAME>_atomic_fetch_or(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```
where *TYPE* is one of the bitwise AMO types and has a corresponding *TYPENAME* specified by Table 6.

DESCRIPTION

Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
OUT	*dest*	A pointer to the remotely accessible data object to be updated.
IN	*value*	The operand to the bitwise OR operation.
IN	*pe*	An integer value for the PE on which *dest* is to be updated.

API description

shmem_atomic_fetch_or atomically performs a fetching bitwise OR on the remotely accessible data object pointed to by *dest* at PE *pe* with the operand *value*. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

Return Values
The value pointed to by *dest* on PE *pe* immediately before the operation is performed.

Notes
    None.

10.8.12 SHMEM_ATOMIC_OR

Atomically perform a non-fetching bitwise OR operation on a remote data object.

SYNOPSIS

    C11:
```
void shmem_atomic_or(TYPE *dest, TYPE value, int pe);
void shmem_atomic_or(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```
    where *TYPE* is one of the bitwise AMO types specified by Table 6.

    C/C++:
```
void shmem_<TYPENAME>_atomic_or(TYPE *dest, TYPE value, int pe);
void shmem_ctx_<TYPENAME>_atomic_or(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```
    where *TYPE* is one of the bitwise AMO types and has a corresponding *TYPENAME* specified by Table 6.

DESCRIPTION

    Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
OUT	*dest*	A pointer to the remotely accessible data object to be updated.
IN	*value*	The operand to the bitwise OR operation.
IN	*pe*	An integer value for the PE on which *dest* is to be updated.

    API description

       shmem_atomic_or atomically performs a non-fetching bitwise OR on the remotely accessible data object pointed to by *dest* at PE *pe* with the operand *value*. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

    Return Values
    None.

    Notes
    None.

10.8.13 SHMEM_ATOMIC_FETCH_XOR

Atomically perform a fetching bitwise exclusive OR (XOR) operation on a remote data object.

SYNOPSIS

    C11:

```
TYPE shmem_atomic_fetch_xor(TYPE *dest, TYPE value, int pe);
TYPE shmem_atomic_fetch_xor(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the bitwise AMO types specified by Table 6.

C/C++:

```
TYPE shmem_<TYPENAME>_atomic_fetch_xor(TYPE *dest, TYPE value, int pe);
TYPE shmem_ctx_<TYPENAME>_atomic_fetch_xor(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the bitwise AMO types and has a corresponding *TYPENAME* specified by Table 6.

DESCRIPTION

    Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.	
OUT	*dest*	A pointer to the remotely accessible data object to be updated.	
IN	*value*	The operand to the bitwise XOR operation.	
IN	*pe*	An integer value for the PE on which *dest* is to be updated.	

    API description

        shmem_atomic_fetch_xor atomically performs a fetching bitwise XOR on the remotely accessible data object pointed to by *dest* at PE *pe* with the operand *value*. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

    Return Values

        The value pointed to by *dest* on PE *pe* immediately before the operation is performed.

    Notes

        None.

10.8.14 SHMEM_ATOMIC_XOR

Atomically perform a non-fetching bitwise exclusive OR (XOR) operation on a remote data object.

SYNOPSIS

    C11:

```
void shmem_atomic_xor(TYPE *dest, TYPE value, int pe);
void shmem_atomic_xor(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the bitwise AMO types specified by Table 6.

    C/C++:

```
void shmem_<TYPENAME>_atomic_xor(TYPE *dest, TYPE value, int pe);
void shmem_ctx_<TYPENAME>_atomic_xor(shmem_ctx_t ctx, TYPE *dest, TYPE value, int pe);
```

where *TYPE* is one of the bitwise AMO types and has a corresponding *TYPENAME* specified by Table 6.

DESCRIPTION

Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.
OUT	*dest*	A pointer to the remotely accessible data object to be updated.
IN	*value*	The operand to the bitwise XOR operation.
IN	*pe*	An integer value for the PE on which *dest* is to be updated.

API description

shmem_atomic_xor atomically performs a non-fetching bitwise XOR on the remotely accessible data object pointed to by *dest* at PE *pe* with the operand *value*. If the context handle *ctx* does not correspond to a valid context, the behavior is undefined.

Return Values
None.

Notes
None.

10.9   Collective Routines

Collective routines are defined as coordinated communication or synchronization operations ~~on~~ performed by a group of PEs ~~called an active set~~.

OpenSHMEM provides two types of collective routines:

1. Collective routines that operate on teams use a team handle parameter to determine which PEs will participate in the routine, and use resources encapsulated by the team object to perform operations. See Section 10.4 for details on team management. These routines will be the standard for OpenSHMEM moving forward.

2. Collective routines that operate on active sets use a set of parameters to determine which PEs will participate and what resources are used to perform operations. These routines are the legacy API for collectives which are deprecated and will be phased out of implementations moving forward.

Collective routines with no team or active set parameters are deprecated, and implicitly operate on the team consisting of all PEs in the computation, *SHMEM_TEAM_WORLD*

The team-based collective routines are performed with respect to a valid OpenSHMEM team, which is specified by a team handle argument. Team-based collective operations require all PEs in the team to call the routine in order for the operation to complete. If an invalid team handle or *SHMEM_TEAM_INVALID* is passed to a team-based collective routine, the behavior is undefined.

Team objects encapsulate the per PE system resources required to complete team-based collective routines. All OpenSHMEM teams-based collective calls are blocking routines which may use those system resources. On completion of a team-based collective call, the PE may immediately call another collective on that same team without any other intervening synchronization across the team.

While OpenSHMEM routines provide thread safety as per the requesting threading model (see 10.2), the teams object itself is not thread-safe. It is up to the program to ensure that on a given PE, there are no simutanously calls to routines on a given team object, including all team based collective calls.

Collective operations are matched across a given team based on ordering. So for a given team, collectives must occur in the same order across all PEs in a team.

The team-based collective routines defined in the OpenSHMEM Specification are:

- *shmem_team_sync*

- *shmem_{TYPE_}broadcast{mem}*

- *shmem_{TYPE_}collect{mem}*

- *shmem_{TYPE_}fcollect{mem}*

- Reduction routines for the following operations: AND, MAX, MIN, SUM, PROD, OR, XOR

- *shmem_{TYPE_}alltoall{mem}*

- *shmem_{TYPE_}alltoalls{mem}*

In addition, all team creation functions are collective operations. In addition to the ordering and thread safety requirements described here, there are additional synchronization requirements on team creation operations. See section 10.4 for more details.

The deprecated function *shmem_sync_all* is provided for backward compatibility to synchronize all PEs in the computation. This should be replaced in applications by the equivalent *shmem_sync(SHMEM_TEAM_WORLD)*.

——— deprecation start ——

The active-set-based collective routines require all PEs in the active set to simultaneously call the routine. A PE that is not in the active set calling the collective routine results in undefined behavior. ~~All collective routines have an active set as an input parameter except~~ *shmem_barrier_all* ~~and~~ *shmem_sync_all*. ~~Both~~ *shmem_barrier_all* ~~and~~ *shmem_sync_all* ~~must be 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* specifies the starting PE number and is the lowest numbered PE in the active set. The stride between successive PEs in the active set is 2^{logPE_stride} and *logPE_stride* must be greater than or equal to zero. *PE_size* specifies the number of PEs in the active set and must be greater than zero. The active set must satisfy the requirement that its last member corresponds to a valid PE number, that is $0 \leq PE\_start + (PE\_size - 1) * 2^{logPE\_stride} < npes$.

All PEs participating in the active-set-based collective routine must provide the same values for these arguments. If any of these requirements are not met, the behavior is undefined.

Another argument important to active-set-based collective routines is *pSync*, which is a symmetric work array. All PEs participating in an active-set-based collective must pass the same *pSync* array. On completion of such 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 active-set-based collective routines. The *shmem_barrier* and *shmem_sync* routines allow the same *pSync* array to be used on consecutive calls as long as the PEs in the active set do not change.

All collective routines defined in the Specification are blocking. The collective routines return on completion. The active-set-based collective routines defined in the OpenSHMEM Specification are:

- *shmem_barrier_all*

- *shmem_barrier*

- *shmem_sync_all*

- *shmem_sync*

- *shmem_broadcast{32, 64}*

- *shmem_collect{32, 64}*

- *shmem_fcollect{32, 64}*

- Reduction routines for the following operations: AND, MAX, MIN, SUM, PROD, OR, XOR

- *shmem_alltoall{32, 64}*

- *shmem_alltoalls{32, 64}*

The active-set-based *shmem_barrier* and routine has been deprecated and no team-based barrier routines will be defined. In future, the behavior previously provided by *shmem_barrier* should be realized by first calling *shmem_ctx_quiet* on any relevant communication contexts followed by a call to *shmem_sync* by some OpenSHMEM team.

Calls to *shmem_barrier_all* should be replaced with a call to quiet the default communication context followed by a call to *shmem_sync* by *SHMEM_TEAM_WORLD*.

——— deprecation end —

10.9.1 SHMEM_BARRIER_ALL

Registers the arrival of a PE at a barrier and blocks the PE until all other PEs arrive at the barrier and all local updates and remote memory updates on the default context are completed.

SYNOPSIS

C/C++:
```
void shmem_barrier_all(void);
```
— deprecation start ———
FORTRAN:
```
CALL SHMEM_BARRIER_ALL
```
——— deprecation end —

DESCRIPTION

Arguments

None.

API description

The *shmem_barrier_all* routine registers the arrival of a PE at a barrier. Barriers are is a mechanism for synchronizing all PEs in the default team at once. This routine blocks the calling PE until all PEs have called *shmem_barrier_all*. In a multithreaded OpenSHMEM program, only the calling thread is blocked, however, it may not be called concurrently by multiple threads in the same PE.

Prior to synchronizing with other PEs, *shmem_barrier_all* ensures completion of all previously issued memory stores and remote memory updates issued on the default context 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

The *shmem_barrier_all* routine is equivalent to calling *shmem_ctx_quiet* on the default context followed by calling *shmem_team_sync* on the default team.

~~The *shmem_barrier_all* routine can be used to portably ensure that memory access operations observe remote updates in the order enforced by initiator PEs.~~

Calls to *shmem_ctx_quiet* can be performed prior to calling the barrier routine to ensure completion of operations issued on additional contexts.

EXAMPLES

The following *shmem_barrier_all* example is for *C11* programs:

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

int main(void)
{
    static int x = 1010;

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

    /* put to next  PE in a circular fashion */
    shmem_p(&x, 4, (me + 1) % npes);

    /* synchronize all PEs */
    shmem_barrier_all();
    printf("%d: x = %d\n", me, x);
    shmem_finalize();
    return 0;
}
```

10.9.2   SHMEM_BARRIER

— deprecation start ——

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);
```
— deprecation start ——
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)
```
—— deprecation end —

DESCRIPTION

Arguments

IN	*PE_start*	The lowest PE number of the active set of PEs. *PE_start* must be of type integer. When 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. When 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. When using *Fortran*, it must be a default integer value.
IN	*pSync*	A symmetric work array of size *SHMEM_BARRIER_SYNC_SIZE*. In *C/C++*, *pSync* must be an array of elements of type *long*. In *Fortran*, *pSync* must be an array of elements of 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, the behavior is undefined.

The values of arguments *PE_start*, *logPE_stride*, and *PE_size* must be the same value 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 on the default context are complete before returning.

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

shmem_barrier has been deprecated in favor of the equivalent call to *shmem_quiet* followed by a call to *shmem_sync* on a team or active set with the desired set of PEs.

Return Values

None.

Notes

If the *pSync* array is initialized at the run time, all PEs must be synchronized before the first call to *shmem_barrier* (e.g., by *shmem_barrier_all*) to ensure the array has been initialized by all PEs before it is used.

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.

The *shmem_barrier* routine can be used to portably ensure that memory access operations observe remote updates in the order enforced by initiator PEs.

Calls to *shmem_ctx_quiet* can be performed prior to calling the barrier routine to ensure completion of operations issued on additional contexts.

No team-based barrier is provided by OpenSHMEM, as a team may have any number of communication contexts associated with the team. Applications seeking such an idiom should call *shmem_ctx_quiet* on the desired context, followed by a call to *shmem_team_sync* on the desired team.

EXAMPLES

The following barrier example is for *C11* programs:

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

int main(void)
{
    static int x = 10101;
    static long pSync[SHMEM_BARRIER_SYNC_SIZE];
    for (int i = 0; i < SHMEM_BARRIER_SYNC_SIZE; i++)
        pSync[i] = SHMEM_SYNC_VALUE;

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

    if (me % 2 == 0) {
        /* put to next even PE in a circular fashion */
        shmem_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);
    shmem_finalize();
    return 0;
}
```

——— deprecation end —

10.9.3   SHMEM_SYNC

Registers the arrival of a PE at a synchronization point and suspends PE execution until all other PEs in a given
OpenSHMEM team or active set arrive at the same synchronization point.

SYNOPSIS

C11:
```
int shmem_sync(shmem_team_t team);
```

C/C++:
```
int shmem_team_sync(shmem_team_t team);
```
—— deprecation start ——
```
void shmem_sync(int PE_start, int logPE_stride, int PE_size, long *pSync);
```
——— deprecation end —

DESCRIPTION

Arguments

IN	*team*	The team over which to perform the operation.	

—— deprecation start ——

IN	*PE_start*	The lowest PE number of the active set of PEs. *PE_start* must be of type integer.	
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.	
IN	*PE_size*	The number of PEs in the active set. *PE_size* must be of type integer.	

| IN | *pSync* | A symmetric work array. In *C/C++*, *pSync* must be of type *long* and size *SHMEM_BARRIER_SYNC_SIZE*. Every element of this array must be initialized to *SHMEM_SYNC_VALUE* before any of the PEs in the active set enter *shmem_sync* the first time. |

— deprecation end —

API description

shmem_sync is a collective synchronization routine over an existing OpenSHMEM team or an active set

The routine registers the arrival of a PE at a synchronization point in the program. This is a fast mechanism for synchronizing all PEs that participate in this collective call. The routine blocks the calling PE until all PE in the specified team or active set have called *shmem_sync*. In a multithreaded OpenSHMEM program, only the calling thread is blocked.

Team-based sync routines operate over all PEs in the provided team argument. All PEs in the provided team must participate in the sync operation. If an invalid team handle or *SHMEM_TEAM_INVALID* is passed to this routine, the behavior is undefined.

Active-set-based sync routines operate over all PEs in the active set defined by the *PE_start*, *logPE_stride*, *PE_size* triplet.

As with all ~~OpenSHMEM~~ active set-based 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~~ active set-based 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 work array must be passed in *pSync* to all PEs in the active set.

In contrast with the *shmem_barrier* routine, *shmem_sync* only ensures completion and visibility of previously issued memory stores and does not ensure completion of remote memory updates issued via Open-SHMEM routines.

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

Return Values

Zero on successful local completion. Nonzero otherwise.

Notes

There are no specifically defined error codes for sync operations. See section 9 for expected error checking and return code behavior specific to implementations. For portable error checking and debugging behavior, programs should do their own checks for invalid team handles or *SHMEM_TEAM_INVALID*

If the *pSync* array is initialized at run time, another method of synchronization (e.g., *shmem_sync_all*) must be used before the initial use of that *pSync* array by *shmem_sync*.

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

The *shmem_sync* routine can be used to portably ensure that memory access operations observe remote updates in the order enforced by the initiator PEs, provided that the initiator PE ensures completion of remote updates with a call to *shmem_quiet* prior to the call to the *shmem_sync* routine.

EXAMPLES

The following *shmem_sync_all* and *shmem_sync* example is for *C11* programs:

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

int main(void)
{
    static int x = 10101;

    shmem_team_t          twos_team, threes_team;
    shmem_team_config_t *config;

    shmem_init();
    config  = NULL;
    int me   = shmem_my_pe();
    int npes = shmem_n_pes();

    int odd_npes = npes % 2;

    shmem_team_split_strided(SHMEM_TEAM_WORLD, 0, 2, npes / 2, config, 0,
                             &twos_team);

    /* The "threes" team below overlaps with the "twos" team, so
     * synchronize on the parent team */
    shmem_sync(SHMEM_TEAM_WORLD);

    shmem_team_split_strided(SHMEM_TEAM_WORLD, 0, 3, npes / 3 + odd_npes,
                             config, 0, &threes_team);

    int my_pe_twos = shmem_team_my_pe(twos_team);
    int my_pe_threes = shmem_team_my_pe(threes_team);

    if (my_pe_twos != SHMEM_TEAM_INVALID) {
        /* put the value 2 to the next team member in a circular fashion */
        shmem_p(&x, 2, (me + 2) % npes);
        shmem_quiet();
        shmem_sync(twos_team);
    }

    if (my_pe_threes != SHMEM_TEAM_INVALID) {
        /* put the value 3 to the next team member in a circular fashion */
        shmem_p(&x, 3, (me + 3) % npes);
        shmem_quiet();
        shmem_sync(threes_team);
    }

    if (me % 3 == 0 && x != 3) {
        shmem_global_exit(3);
    }
    else if (me % 2 == 0 && x != 2) {
        shmem_global_exit(2);
    }
    else if (x != 10101) {
        shmem_global_exit(1);
    }

    shmem_finalize();
    return 0;
}
```

10.9.4   SHMEM_SYNC_ALL

— deprecation start ———

Performs all operations described in the *shmem_sync* interface but implicitly operates on *SHMEM_TEAM_WORLD*.

SYNOPSIS

C/C++:
```
void shmem_sync_all(void);
```

DESCRIPTION

Arguments

None.

API description

This routine blocks the PE until all PEs in the OpenSHMEM program have called *shmem_sync_all*. In a multithreaded OpenSHMEM program, only the calling thread is blocked.

In contrast with the *shmem_barrier_all* routine, *shmem_sync_all* only ensures completion and visibility of previously issued memory stores and does not ensure completion of remote memory updates issued via OpenSHMEM routines.

The *shmem_sync_all* routine is deprecated in favor of the equivalent call to *shmem_sync(SHMEM_TEAM_WORLD)*.

Return Values
None.

Notes
None.

——— deprecation end —

10.9.5 SHMEM_BROADCAST

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

SYNOPSIS

C11:
```
int shmem_broadcast(shmem_team_t team, TYPE *dest, const TYPE *source, size_t nelems, int
    PE_root);
```
where *TYPE* is one of the standard RMA types specified by Table 3.

C/C++:
```
int shmem_<TYPENAME>_broadcast(shmem_team_t team, TYPE *dest, const TYPE *source, size_t
    nelems, int PE_root);
```
where *TYPE* is one of the standard RMA types and has a corresponding *TYPENAME* specified by Table 3.
```
int shmem_broadcastmem(shmem_team_t team, void *dest, const void *source, size_t nelems, int
    PE_root);
```
— deprecation start ———————————————————————————————————————
```
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);
```

—— deprecation end —

—— deprecation start ——

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)
```

—— deprecation end —

DESCRIPTION

Arguments

IN	*team*	The team over which to perform the operation.	
OUT	*dest*	A symmetric data object. See the table below in this description for allowable types.	
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*. nelems must be of type *size_t* in *C*. When using *Fortran*, it must be a default integer value.	
IN	*PE_root*	Zero-based ordinal of the PE, with respect to the team or active set, from which the data is copied. *PE_root* must be of type *int*. When using *Fortran*, it must be a default integer value.	

—— deprecation start ——

IN	*PE_start*	The lowest PE number of the active set of PEs. *PE_start* must be of type integer. When 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. When 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. When using *Fortran*, it must be a default integer value.
IN	*pSync*	A symmetric work array of size *SHMEM_BCAST_SYNC_SIZE*. In *C/C++*, *pSync* must be an array of elements of type *long*. In *Fortran*, *pSync* must be an array of elements of default integer type. Every element of this array must be initialized with the value *SHMEM_SYNC_VALUE* before any of the PEs in the active set enters *shmem_broadcast*.

—— deprecation end —

API description

OpenSHMEM broadcast routines are collective routines over an active set or existing OpenSHMEM team. They copy data object *source* on the processor specified by *PE_root* and store the values at *dest* on the other PEs particpating in the collective operation. specified by the triplet *PE_start, logPE_stride, PE_size.* The data is not copied to the *dest* area on the root PE.

The same *dest* and *source* data objects and the same value of *PE_root* must be passed by all PEs particpating in the collective operation.

Team-based broadcast routines operate over all PEs in the provided team argument. All PEs in the provided team must participate in the operation. If an invalid team handle or *SHMEM_TEAM_INVALID* is passed to this routine, the behavior is undefined.

As with all team-based OpenSHMEM routines, PE numbering is relative to the team. The specified root PE must be a valid PE number for the team, between *0* and *N-1*, where *N* is the size of the team.

Active-set-based broadcast routines operate over all PEs in the active set defined by the *PE_start*, *logPE_stride*, *PE_size* triplet.

As with all active-set-based ~~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 active-set-based ~~OpenSHMEM~~ collective routine, the behavior is undefined.

The values of arguments *PE_root*, *PE_start*, *logPE_stride*, and *PE_size* must be the same value on all PEs in the active set. The value of *PE_root* must be between *0* and *PE_size*. The same *pSync* work array must be passed by all PEs in the active set.

Before any PE calls a broadcast routine, the following conditions must be ensured:

- The *dest* array on all PEs participating in the broadcast ~~in the active set~~ is ready to accept the broadcast data.
- If using active-set-based routines, the *pSync* array on all PEs in the active set is not still in use from a prior call to a collective OpenSHMEM routine.

Otherwise, the behavior is undefined.

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 *source* data object may be safely reused.
- If using active-set-based routines, 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_broadcastmem	*C*: Any data type. nelems is scaled in bytes.
shmem_broadcast8, shmem_broadcast64	Any noncharacter type that has an element size of *64* bits. No *Fortran* derived types nor ~~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 nor ~~or~~ *C/C++* structures are allowed.

Return Values

Zero on successful local completion. Nonzero otherwise.

Notes

There are no specifically defined error codes for these routines. See section 9 for expected error checking and return code behavior specific to implementations. For portable error checking and debugging behavior, programs should do their own checks for invalid team handles or *SHMEM_TEAM_INVALID*

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.

The user must ensure 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, before its first use, 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 Open-SHMEM 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.

Team handle error checking and integer return codes are currently undefined. Implementations may define these behaviors as needed, but programs should ensure portability by doing their own checks for invalid team handles and for *SHMEM_TEAM_INVALID*.

EXAMPLES

In the following *C11* example, the call to *shmem_broadcast* copies *source* on PE 0 to *dest* on PEs $1 \ldots npes - 1$.

C/C++ example:

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

int main(void)
{
    static long source[4], dest[4];

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

    if (me == 0)
        for (int i = 0; i < 4; i++)
            source[i] = i;

    shmem_broadcast(SHMEM_TEAM_WORLD, dest, source, 4, 0);

    printf("%d: %ld, %ld, %ld, %ld\n", me, dest[0], dest[1], dest[2], dest[3]);
    shmem_finalize();
    return 0;
}
```

10.9.6   SHMEM_COLLECT, SHMEM_FCOLLECT

Concatenates blocks of data from multiple PEs to an array in every PE participating in the collective routine.

SYNOPSIS

C11:
```
int shmem_collect(shmem_team_t team, TYPE *dest, const TYPE *source, size_t nelems);
int shmem_fcollect(shmem_team_t team, TYPE *dest, const TYPE *source, size_t nelems);
```
where *TYPE* is one of the standard RMA types specified by Table 3.

C/C++:
```
int shmem_<TYPENAME>_collect(shmem_team_t team, TYPE *dest, const TYPE *source, size_t
    nelems);
int shmem_<TYPENAME>_fcollect(shmem_team_t team, TYPE *dest, const TYPE *source, size_t
    nelems);
```
where *TYPE* is one of the standard RMA types and has a corresponding *TYPENAME* specified by Table 3.
```
int shmem_collectmem(shmem_team_t team, void *dest, const void *source, size_t nelems);
int shmem_fcollectmem(shmem_team_t team, void *dest, const void *source, size_t nelems);
```
—— deprecation start ——
```
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);
```

—— deprecation end —

— deprecation start ——

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)
```

—— deprecation end —

DESCRIPTION

   Arguments

IN	*team*	A valid OpenSHMEM team handle.
OUT	*dest*	A symmetric array large enough to accept the concatenation of the *source* arrays on all participating PEs. See table below in this description for allowable data types.
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*. When using *Fortran*, it must be a default integer value.

   — deprecation start ——

IN	*PE_start*	The lowest PE number of the active set of PEs. *PE_start* must be of type integer. When 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. When 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. When using *Fortran*, it must be a default integer value.
IN	*pSync*	A symmetric work array of size *SHMEM_COLLECT_SYNC_SIZE*. In *C/C++*, *pSync* must be an array of elements of type *long*. In *Fortran*, *pSync* must be an array of elements of default integer type. Every element of this array must be initialized with the value *SHMEM_SYNC_VALUE* before any of the PEs in the active set enter *shmem_collect* or *shmem_fcollect*.

   —— deprecation end —

API description

OpenSHMEM *collect* and *fcollect* routines perform a collective operation to concatenate *nelems* data items from the *source* array into the *dest* array, over an OpenSHMEM team or active set in processor number order. The resultant *dest* array contains the contribution from PEs as follows:

- For an active set, the data from PE *PE_start* is first, then the contribution from PE *PE_start + PE_stride* second, and so on.
- For a team, the data from PE number *0* in the team is first, then the contribution from PE *1* in the team, and so on.

The collected result is written to the *dest* array for all PEs that participate in the operation. The same *dest* and *source* arrays must be passed by all PEs that participate in the operation.

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.

Team-based collect routines operate over all PEs in the provided team argument. All PEs in the provided team must participate in the operation.

Active-set-based collective routines operate over all PEs in the active set defined by the *PE_start*, *logPE_stride*, *PE_size* triplet. As with all active-set-based 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 the same value on all PEs in the active set. The same ~~dest~~ and ~~source~~ ~~arrays and the same~~ *pSync* work array must be passed by 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 and the *source* array may be safely reused.
- For active-set-based collective routines, 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_collectmem, *shmem_fcollectmem*	*C*: Any data type. *nelems* is scaled in bytes.
shmem_collect8, *shmem_collect64*, *shmem_fcollect8*, *shmem_fcollect64*	Any noncharacter type that has an element size of *64* bits. No *Fortran* derived types nor *C/C++* structures are allowed.
shmem_collect4, *shmem_collect32*, *shmem_fcollect4*, *shmem_fcollect32*	Any noncharacter type that has an element size of *32* bits. No *Fortran* derived types nor *C/C++* structures are allowed.

Return Values

Zero on successful local completion. Nonzero otherwise.

Notes

There are no specifically defined error codes for these routines. See section 9 for expected error checking and return code behavior specific to implementations. For portable error checking and debugging behavior, programs should do their own checks for invalid team handles or *SHMEM_TEAM_INVALID*.

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.

The user 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 perfor-
mance 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:

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

int main(void)
{
    static long lock = 0;

    shmem_init();
    int me = shmem_my_pe();
    int npes = shmem_n_pes();
    int my_nelem = me + 1; /* linearly increasing number of elements with PE */
    int total_nelem = (npes * (npes + 1)) / 2;

    int* source = (int*) shmem_malloc(npes*sizeof(int)); /* symmetric alloc */
    int* dest = (int*) shmem_malloc(total_nelem*sizeof(int));

    for (int i = 0; i < my_nelem; i++)
        source[i] = (me * (me + 1)) / 2 + i;
    for (int i = 0; i < total_nelem; i++)
        dest[i] = -9999;

    /* Wait for all PEs to initialize source/dest: */
    shmem_team_sync(SHMEM_TEAM_WORLD);

    shmem_int_collect(SHMEM_TEAM_WORLD, dest, source, my_nelem);

    shmem_set_lock(&lock); /* Lock prevents interleaving printfs */
    printf("%d: %d", me, dest[0]);
    for (int i = 1; i < total_nelem; i++)
        printf(", %d", dest[i]);
    printf("\n");
    shmem_clear_lock(&lock);
    shmem_finalize();
    return 0;
}
```

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

```fortran
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)
```

10.9.7 SHMEM_REDUCTIONS

The following functions perform reduction operations across all PEs in a set of PEs.

SYNOPSIS

TYPE	TYPENAME	Operations Supporting TYPE		
unsigned char	uchar	AND, OR, XOR		
short	short	AND, OR, XOR	MAX, MIN	SUM, PROD
unsigned short	ushort	AND, OR, XOR	MAX, MIN	SUM, PROD
int	int	AND, OR, XOR	MAX, MIN	SUM, PROD
unsigned int	uint	AND, OR, XOR	MAX, MIN	SUM, PROD
long	long	AND, OR, XOR	MAX, MIN	SUM, PROD
unsigned long	ulong	AND, OR, XOR	MAX, MIN	SUM, PROD
long long	longlong	AND, OR, XOR	MAX, MIN	SUM, PROD
unsigned long long	ulonglong	AND, OR, XOR	MAX, MIN	SUM, PROD
float	float		MAX, MIN	SUM, PROD
double	double		MAX, MIN	SUM, PROD
long double	longdouble		MAX, MIN	SUM, PROD
double _Complex	complexd			SUM, PROD
float _Complex	complexf			SUM, PROD

Table 7: Reduction Types, Names and Supporting Operations

10.9.7.1 AND   Performs a bitwise AND reduction across a set of PEs.

C11:
```
int shmem_and_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t nreduce);
```
where *TYPE* is one of the integer types supported for the AND operation as specified by Table 7.

C/C++:
```
int shmem_<TYPENAME>_and_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t
    nreduce);
```
—— deprecation start ——————————————————————————————————
```
void shmem_<TYPENAME>_and_to_all(TYPE *dest, const TYPE *source, int nreduce, int PE_start,
    int logPE_stride, int PE_size, short *pWrk, long *pSync);
```
——— deprecation end ——

where *TYPE* is one of the integer types supported for the AND operation and has a corresponding *TYPENAME* as specified by Table 7.

—— deprecation start ——————————————————————————————————
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)
```
——— deprecation end ——

10.9.7.2 OR   Performs a bitwise OR reduction across a set of PEs.

C11:

```
int shmem_or_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t nreduce);
```

where *TYPE* is one of the integer types supported for the OR operation as specified by Table 7.

C/C++:

```
int shmem_<TYPENAME>_or_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t
    nreduce);
```

—— deprecation start ——

```
void shmem_<TYPENAME>_or_to_all(TYPE *dest, const TYPE *source, int nreduce, int PE_start,
    int logPE_stride, int PE_size, short *pWrk, long *pSync);
```

——— deprecation end ——

where *TYPE* is one of the integer types supported for the OR operation and has a corresponding *TYPENAME* as specified by Table 7.

—— deprecation start ——

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)
```

——— deprecation end ——

10.9.7.3 XOR Performs a bitwise exclusive OR (XOR) reduction across a set of PEs.

C11:

```
int shmem_xor_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t nreduce);
```

where *TYPE* is one of the integer types supported for the XOR operation as specified by Table 7.

C/C++:

```
int shmem_<TYPENAME>_xor_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t
    nreduce);
```

—— deprecation start ——

```
void shmem_<TYPENAME>_xor_to_all(TYPE *dest, const TYPE *source, int nreduce, int PE_start,
    int logPE_stride, int PE_size, short *pWrk, long *pSync);
```

——— deprecation end ——

where *TYPE* is one of the integer types supported for the XOR operation and has a corresponding *TYPENAME* as specified by Table 7.

—— deprecation start ——

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)
```

——— deprecation end ——

10.9.7.4 MAX Performs a maximum-value reduction across a set of PEs.

C11:

```
int shmem_max_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t nreduce);
```

where *TYPE* is one of the integer or real types supported for the MAX operation as specified by Table 7.

C/C++:

```
int shmem_<TYPENAME>_max_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t
    nreduce);
```

—— deprecation start ——

```
void shmem_<TYPENAME>_max_to_all(TYPE *dest, const TYPE *source, int nreduce, int PE_start,
    int logPE_stride, int PE_size, short *pWrk, long *pSync);
```

——— deprecation end ——

where *TYPE* is one of the integer or real types supported for the MAX operation and has a corresponding *TYPENAME* as specified by Table 7.

—— deprecation start ——

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)
```

——— deprecation end ——

10.9.7.5   MIN   Performs a minimum-value reduction across a set of PEs.

C11:

```
int shmem_min_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t nreduce);
```

where *TYPE* is one of the integer or real types supported for the MIN operation as specified by Table 7.

C/C++:

```
int shmem_<TYPENAME>_min_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t
    nreduce);
```

—— deprecation start ——

```
void shmem_<TYPENAME>_min_to_all(TYPE *dest, const TYPE *source, int nreduce, int PE_start,
    int logPE_stride, int PE_size, short *pWrk, long *pSync);
```

——— deprecation end ——

where *TYPE* is one of the integer or real types supported for the MIN operation and has a corresponding *TYPENAME* as specified by Table 7.

—— deprecation start ——

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)
```

——— deprecation end ——

10.9.7.6 SUM Performs a sum reduction across a set of PEs.

C11:

```
int shmem_sum_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t nreduce);
```

where *TYPE* is one of the integer, real, or complex types supported for the SUM operation as specified by Table 7.

C/C++:

```
int shmem_<TYPENAME>_sum_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t
    nreduce);
```

—— deprecation start ——

```
void shmem_<TYPENAME>_sum_to_all(TYPE *dest, const TYPE *source, int nreduce, int PE_start,
    int logPE_stride, int PE_size, short *pWrk, long *pSync);
```

—— deprecation end ——

where *TYPE* is one of the integer, real, or complex types supported for the SUM operation and has a corresponding *TYPENAME* as specified by Table 7.

—— deprecation start ——

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)
```

—— deprecation end ——

10.9.7.7 PROD Performs a product reduction across a set of PEs.

C11:

```
int shmem_prod_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t nreduce);
```

where *TYPE* is one of the integer, real, or complex types supported for the PROD operation as specified by Table 7.

C/C++:

```
int shmem_<TYPENAME>_prod_reduce(shmem_team_t team, TYPE *dest, const TYPE *source, size_t
    nreduce);
```

—— deprecation start ——

```
void shmem_<TYPENAME>_prod_to_all(TYPE *dest, const TYPE *source, int nreduce, int PE_start,
    int logPE_stride, int PE_size, short *pWrk, long *pSync);
```

—— deprecation end ——

where *TYPE* is one of the integer, real, or complex types supported for the PROD operation and has a corresponding *TYPENAME* as specified by Table 7.

—— deprecation start ——

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)
```

—— deprecation end —

DESCRIPTION

Arguments

IN	*team*	The team over which to perform the operation.
OUT	*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. In teams based API calls, *nreduce* must be of type size_t. In deprecated active-set based API calls, *nreduce* must be of type int. When using *Fortran*, it must be a default integer value.

— deprecation start ——

IN	*PE_start*	The lowest PE number of the active set of PEs. *PE_start* must be of type integer. When 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. When 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. When using *Fortran*, it must be a default integer value.
IN	*pWrk*	A symmetric work array of size at least max(*nreduce*/2 + 1, *SHMEM_REDUCE_MIN_WRKDATA_SIZE*) elements.
IN	*pSync*	A symmetric work array of size *SHMEM_REDUCE_SYNC_SIZE*. In *C/C++*, *pSync* must be an array of elements of type *long*. In *Fortran*, *pSync* must be an array of elements of default integer type. 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 reduction routine.

—— deprecation end —

API description

OpenSHMEM reduction routines are collective routines over an active set or existing OpenSHMEM team that 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 participating in the reduction in the active set provides one element for each reduction. The results of the reductions are placed in the *dest* array on all PEs participating in the reduction. in the active set.

The *source* and *dest* arrays may be the same array, but they may not be overlapping arrays. The same *dest* and *source* arrays must be passed to all PEs participating in the reduction. in the active set.

Team-based reduction routines operate over all PEs in the provided team argument. All PEs in the provided team must participate in the reduction. If an invalid team handle or *SHMEM_TEAM_INVALID* is passed to this routine, the behavior is undefined.

Active-set-based sync routines operate over all PEs in the active set defined by the *PE_start*, *logPE_stride*, *PE_size* triplet.

As with all OpenSHMEM active set-based 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 active set-based collective routine, the behavior is undefined.

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

Before any PE calls a reduction routine, the following conditions must be ensured:

- The *dest* array on all PEs participating in the reduction in the active set is ready to accept the results of the *reduction*.
- If using active-set-based routines, 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.

Otherwise, the behavior is undefined.

Upon return from a reduction routine, the following are true for the local PE:

- The *dest* array is updated and the *source* array may be safely reused.
- If using active-set-based routines, the values in the *pSync* array are restored to the original values.

The complex-typed interfaces are only provided for sum and product reductions. When the *C* translation environment does not support complex types [7], an OpenSHMEM implementation is not required to provide support for these complex-typed interfaces.

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.

---

[7]That is, under *C* language standards prior to *C99* or under *C11* when *__STDC_NO_COMPLEX__* is defined to 1

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

Zero on successful local completion. Nonzero otherwise.

Notes

There are no specifically defined error codes for this routine. See section 9 for expected error checking and return code behavior specific to implementations. For portable error checking and debugging behavior, programs should do their own checks for invalid team handles or *SHMEM_TEAM_INVALID*

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. The user 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 *C/C++* reduction example gets integers from an external source (random genererator in this example), tests to see if the PE got a valid value, and outputs the sum of values for which all PEs got a valid value.

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

/* As if we receive some value from external source */
long recv_a_value(unsigned seed, int npes) {
  srand(seed);
  return rand() % npes;
}

/* Validate the value we recieved */
unsigned char is_valid(long value, int npes) {
  if (value == (npes-1))
    return 0;
```

```
    return 1;
}

int main(void)
{

  shmem_init();
  int me = shmem_my_pe();
  int npes = shmem_n_pes();
  size_t num = 32;

  long *values = shmem_malloc(num * sizeof(int));
  long *sums = shmem_malloc(num * sizeof(int));

  unsigned char *valid_me = shmem_malloc(num * sizeof(int));
  unsigned char *valid_all = shmem_malloc(num * sizeof(int));

  values[0] = recv_a_value((unsigned)me, npes);
  valid_me[0] = is_valid(values[0], npes);

  for (int i=1; i < num; i++) {
    values[i] = recv_a_value((unsigned)values[i-1], npes);
    valid_me[i] = is_valid(values[i], npes);
  }

  /* Wait for all PEs to initialize reductions arrays */
  shmem_sync(SHMEM_TEAM_WORLD);

#if __STDC_VERSION__ >= 201112
  /* C11 generic interface */
  shmem_and_reduce(SHMEM_TEAM_WORLD, valid_all, valid_me, num);
  shmem_sum_reduce(SHMEM_TEAM_WORLD, sums, values, num);
#else
  /* C/C++ interface without generic support */
  shmem_uchar_and_reduce(SHMEM_TEAM_WORLD, valid_all, valid_me, num);
  shmem_long_sum_reduce(SHMEM_TEAM_WORLD, sums, values, num);
#endif

  for (int i=0; i < num; i++) {
    if (valid_all[i]) {
      printf ("[%d] = %ld\n", i, sums[i]);
    }
    else {
      printf ("[%d] = invalid on one or more pe\n", i);
    }
  }
}
```

10.9.8 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~~ participating in the collective.

SYNOPSIS

C11:
```
int shmem_alltoall(shmem_team_t team, TYPE *dest, const TYPE *source, size_t nelems);
```
where *TYPE* is one of the standard RMA types specified by Table 3.

C/C++:
```
int shmem_<TYPENAME>_alltoall(shmem_team_t team, TYPE *dest, const TYPE *source, size_t
    nelems);
```
where *TYPE* is one of the standard RMA types and has a corresponding *TYPENAME* specified by Table 3.
```
int shmem_alltoallmem(shmem_team_t team, void *dest, const void *source, size_t nelems);
```

```
— deprecation start —————————————————————————————————————————————
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);
————————————————————————————————————————————————————— deprecation end —
```

```
— deprecation start —————————————————————————————————————————————
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)
————————————————————————————————————————————————————— deprecation end —
```

DESCRIPTION

Arguments

IN	*team*	A valid OpenSHMEM team handle to a team.
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++*. When using *Fortran*, it must be a default integer value.

```
— deprecation start —————————————————————————————————————————————
```

IN	*PE_start*	The lowest PE number of the active set of PEs. *PE_start* must be of type integer. When 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. When 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. When using *Fortran*, it must be a default integer value.
IN	*pSync*	A symmetric work array of size *SHMEM_ALLTOALL_SYNC_SIZE*. In *C/C++*, *pSync* must be an array of elements of type *long*. In *Fortran*, *pSync* must be an array of elements of default integer type. 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.

```
————————————————————————————————————————————————————— deprecation end —
```

API description

The *shmem_alltoall* routines are collective routines. Each PE participating in the operation exchanges *nelems* data elements with all other PEs participating in the operation. The size of a data element is:

- 32 bits for *shmem_alltoall32*
- 64 bits for *shmem_alltoall64*
- 8 bits for *shmem_alltoallmem*

- *sizeof*(*TYPE*) for alltoall routines taking typed *source* and *dest*

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*~~ times *N*, where *N* equals the number of PEs participating in the operation. The *source* object contains ~~oldtext*PE_size*~~ *N* blocks of data (where the size of each block is defined by *nelems*) and each block of data is sent to a different PE.

The same *dest* and *source* arrays, and same value for nelems must be passed by all PEs that participate in the collective.

Given a PE *i* that is the kth PE ~~in the active set~~ participating in the operation and a PE *j* that is the lth PE ~~in the active set~~ participating in the operation, PE *i* sends the lth block of its *source* object to the kth block of the *dest* object of PE *j*.

Team-based collect routines operate over all PEs in the provided team argument. All PEs in the provided team must participate in the collective.

Active-set-based collective routines operate over all PEs in the active set defined by the *PE_start*, *logPE_stride*, *PE_size* triplet. As with all ~~OpenSHMEM~~ active-set-based 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~~ active-set-based collective routine, the behavior is undefined.

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 be ensured:

- The *dest* data object on all PEs in the active set is ready to accept the *shmem_alltoall* data.
- For active-set-based routines, the *pSync* array on all PEs in the active set is not still in use from a prior call to a *shmem_alltoall* routine.

Otherwise, the behavior is undefined.

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.
- For active-set-based routines, 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

Zero on successful local completion. Nonzero otherwise.

Notes

There are no specifically defined error codes for these routines. See section 9 for expected error checking and return code behavior specific to implementations. For portable error checking and debugging behavior, programs should do their own checks for invalid team handles or *SHMEM_TEAM_INVALID*.

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. The user must ensure 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 *C/C++* example shows a *shmem_int64_alltoall* on two 64-bit integers among all PEs.

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

int main(void)
{
    shmem_init();
    int me = shmem_my_pe();
    int npes = shmem_n_pes();

    const int count = 2;
    int64_t* dest = (int64_t*) shmem_malloc(count * npes * sizeof(int64_t));
    int64_t* source = (int64_t*) shmem_malloc(count * npes * sizeof(int64_t));

    /* assign source values */
    for (int pe = 0; pe < npes; pe++) {
        for (int i = 0; i < count; i++) {
            source[(pe * count) + i] = me + pe;
            dest[(pe * count) + i] = 9999;
        }
    }
    /* wait for all PEs to initialize source/dest */
    shmem_team_sync(SHMEM_TEAM_WORLD);

    /* alltoall on all PES */
    shmem_int64_alltoall(SHMEM_TEAM_WORLD, dest, source, count);

    /* verify results */
    for (int pe = 0; pe < npes; pe++) {
        for (int i = 0; i < count; i++) {
            if (dest[(pe * count) + i] != pe + me) {
                printf("[%d] ERROR: dest[%d]=%" PRId64 ", should be %d\n",
                    me, (pe * count) + i, dest[(pe * count) + i], pe + me);
            }
        }
    }

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

10.9.9   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~~ participating in the collective.

SYNOPSIS

    C11:

```
int shmem_alltoalls(shmem_team_t team, TYPE *dest, const TYPE *source, ptrdiff_t dst,
    ptrdiff_t sst, size_t nelems);
```

where *TYPE* is one of the standard RMA types specified by Table 3.

C/C++:

```
int shmem_<TYPENAME>_alltoalls(shmem_team_t team, TYPE *dest, const TYPE *source, ptrdiff_t
    dst, ptrdiff_t sst, size_t nelems);
```

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

```
int shmem_alltoallsmem(shmem_team_t team, void *dest, const void *source, ptrdiff_t dst,
    ptrdiff_t sst, size_t nelems);
```

— deprecation start ———

```
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);
```

——— deprecation end —

— deprecation start ———

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)
```

——— deprecation end —

DESCRIPTION

Arguments

IN	*team*	A valid OpenSHMEM team handle.
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*. When 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*. When using *Fortran*, it must be a default integer value.

— deprecation start ———————————————————————————————————————

IN	*nelems*	The number of elements to exchange for each PE. *nelems* must be of type size_t for *C/C++*. When 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. When 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. When 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. When using *Fortran*, it must be a default integer value.
IN	*pSync*	A symmetric work array of size *SHMEM_ALLTOALLS_SYNC_SIZE*. In *C/C++*, *pSync* must be an array of elements of type *long*. In *Fortran*, *pSync* must be an array of elements of default integer type. 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.

— deprecation end —

API description

The *shmem_alltoalls* routines are collective routines. These routines are equivalent in functionality to the corresponding *shmem_alltoall* routines except that they add explicit stride values for accessing the source and destination data arrays, whereas the array access in *shmem_alltoall* is always with a stride of *1*.

Each PE in the active set participating in the operation 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 participating in the operation. Both strides, *dst* and *sst*, must be greater than or equal to *1*.

The same *dest* and *source* arrays and same values for values of arguments *dst*, *sst*, *nelems* must be passed by all PEs that participate in the collective.

Given a PE *i* that is the *k*ᵗʰ PE in the active set participating in the operation and a PE *j* that is the *l*ᵗʰ PE in the active set participating in the operation PE *i* sends the *sst*l*ᵗʰ block of the *source* data object to the *dst*k*ᵗʰ block of the *dest* data object on PE *j*.

See the description of *shmem_alltoall* in section 10.9.8 for:

- Data element sizes for the different sized and typed *shmem_alltoalls* variants.
- Rules for PE participation in the collective routine.
- The pre- and post-conditions for symmetric objects.
- Typing constraints for *dest* and *source* data objects.

Return Values

Zero on successful local completion. Nonzero otherwise.

Notes

See notes for *shmem_alltoall* in section 10.9.8.

EXAMPLES

This *C/C++* example shows a *shmem_int64_alltoalls* on two 64-bit integers among all PEs.

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

int main(void)
{
    shmem_init();
    int me = shmem_my_pe();
    int npes = shmem_n_pes();
```

```
      const int count = 2;
      const ptrdiff_t dst = 2;
      const ptrdiff_t sst = 3;
      int64_t* dest = (int64_t*) shmem_malloc(count * dst * npes * sizeof(int64_t));
      int64_t* source = (int64_t*) shmem_malloc(count * sst * npes * sizeof(int64_t));

      /* assign source values */
      for (int pe = 0; pe < npes; pe++) {
         for (int i = 0; i < count; i++) {
            source[sst * ((pe * count) + i)] = me + pe;
            dest[dst * ((pe * count) + i)] = 9999;
         }
      }
      /* wait for all PEs to initialize source/dest */
      shmem_team_sync(SHMEM_TEAM_WORLD);

      /* alltoalls on all PES */
      shmem_int64_alltoalls(SHMEM_TEAM_WORLD, dest, source, dst, sst, count);

      /* verify results */
      for (int pe = 0; pe < npes; pe++) {
         for (int i = 0; i < count; i++) {
            int j = dst * ((pe * count) + i);
            if (dest[j] != pe + me) {
               printf("[%d] ERROR: dest[%d]=%" PRId64 ", should be %d\n",
                  me, j, dest[j], pe + me);
            }
         }
      }

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

10.10 Point-To-Point Synchronization Routines

The following section discusses OpenSHMEM APIs that provide a mechanism for synchronization between two PEs based on the value of a symmetric data object. The point-to-point synchronization routines can be used to portably ensure that memory access operations observe remote updates in the order enforced by the initiator PE using the *shmem_fence* and *shmem_quiet* routines.

Where appropriate compiler support is available, OpenSHMEM provides type-generic point-to-point synchronization interfaces via *C11* generic selection. Such type-generic routines are supported for the "point-to-point synchronization types" identified in Table 8.

The point-to-point synchronization types include some of the exact-width integer types defined in *stdint.h* by *C99* §7.18.1.1 and *C11* §7.20.1.1. When the *C* translation environment does not provide exact-width integer types with *stdint.h*, an OpenSHMEM implemementation is not required to provide support for these types.

The point-to-point synchronization interface provides named constants whose values are integer constant expressions that specify the comparison operators used by OpenSHMEM synchronization routines. The constant names and associated operations are presented in Table 9. For Fortran, the constant names of Table 9 shall be identifiers for integer parameters of default kind corresponding to the associated comparison operation.

10.10.1 SHMEM_WAIT_UNTIL

Wait for a variable on the local PE to change.

SYNOPSIS

TYPE	TYPENAME
short	short
int	int
long	long
long long	longlong
unsigned short	ushort
unsigned int	uint
unsigned long	ulong
unsigned long long	ulonglong
int32_t	int32
int64_t	int64
uint32_t	uint32
uint64_t	uint64
size_t	size
ptrdiff_t	ptrdiff

Table 8: Point-to-Point Synchronization Types and Names

Constant Name	Comparison
SHMEM_CMP_EQ	Equal
SHMEM_CMP_NE	Not equal
SHMEM_CMP_GT	Greater than
SHMEM_CMP_GE	Greater than or equal to
SHMEM_CMP_LT	Less than
SHMEM_CMP_LE	Less than or equal to

Table 9: Point-to-Point Comparison Constants

C11:

```
void shmem_wait_until(TYPE *ivar, int cmp, TYPE cmp_value);
```

where *TYPE* is one of the point-to-point synchronization types specified by Table 8.

C/C++:

```
void shmem_<TYPENAME>_wait_until(TYPE *ivar, int cmp, TYPE cmp_value);
```

where *TYPE* is one of the point-to-point synchronization types and has a corresponding *TYPENAME* specified by Table 8.

— deprecation start ———

```
void shmem_wait_until(long *ivar, int cmp, long cmp_value);
void shmem_wait(long *ivar, long cmp_value);
void shmem_<TYPENAME>_wait(TYPE *ivar, TYPE cmp_value);
```

where *TYPE* is one of {*short*, *int*, *long*, *long long*} and has a corresponding *TYPENAME* specified by Table 8.

——— deprecation end —

— deprecation start ———

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)
```

—————————————————————————————————— deprecation end —

DESCRIPTION

Arguments

OUT	*ivar*	A remotely accessible integer variable. When 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*. When using *Fortran*, it must be of default kind. When using *C/C++*, it must be of type *int*.
IN	*cmp_value*	*cmp_value* must be of type integer. When using *C/C++*, the type of *cmp_value* should match that implied in the SYNOPSIS section. When using *Fortran*, cmp_value must be an integer of the same size and kind as *ivar*.

API description

The *shmem_wait* and *shmem_wait_until* operations block until the value contained in the symmetric data object, *ivar*, at the calling PE satisfies the wait condition. In an OpenSHMEM program with single-threaded PEs, the *ivar* object at the calling PE may be updated by an RMA, AMO, or store operation performed by another PE. In an OpenSHMEM program with multithreaded PEs, the *ivar* object at the calling PE may be updated by an RMA, AMO, or store operation performed by a thread located within the calling PE or within another PE.

These routines can be used to implement point-to-point synchronization between PEs or between threads within the same PE. A call to *shmem_wait* blocks until the value of *ivar* at the calling PE is not equal to *cmp_value*. A call to *shmem_wait_until* blocks until the value of *ivar* at the calling PE satisfies the wait condition specified by the comparison operator, *cmp*, and comparison value, *cmp_value*.

When 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

Return Values
None.

Notes
As of OpenSHMEM 1.4, the *shmem_wait* routine is deprecated; however, *shmem_wait* is equivalent to *shmem_wait_until* where *cmp* is *SHMEM_CMP_NE*.

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 value in *ivar* is set to be less than zero 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
```

10.10.2   SHMEM_TEST

Test whether a variable on the local PE has changed.

SYNOPSIS

C11:
```
int shmem_test(TYPE *ivar, int cmp, TYPE cmp_value);
```
where *TYPE* is one of the point-to-point synchronization types specified by Table 8.

C/C++:
```
int shmem_<TYPENAME>_test(TYPE *ivar, int cmp, TYPE cmp_value);
```
where *TYPE* is one of the point-to-point synchronization types and has a corresponding *TYPENAME* specified by Table 8.

DESCRIPTION

Arguments

OUT	*ivar*	A pointer to a remotely accessible data object.
IN	*cmp*	The comparison operator that compares *ivar* with *cmp_value*.
IN	*cmp_value*	The value against which the object pointed to by *ivar* will be compared.

API description

shmem_test tests the numeric comparison of the symmetric object pointed to by *ivar* with the value *cmp_value* according to the comparison operator *cmp*.

Return Values

shmem_test returns 1 if the comparison of the symmetric object pointed to by *ivar* with the value *cmp_value* according to the comparison operator *cmp* evaluates to true; otherwise, it returns 0.

Notes

None.

EXAMPLES

The following example demonstrates the use of *shmem_test* to wait on an array of symmetric objects and return the index of an element that satisfies the specified condition.

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

int user_wait_any(long *ivar, int count, int cmp, long value)
{
  int idx = 0;
  while (!shmem_test(&ivar[idx], cmp, value))
    idx = (idx + 1) % count;
  return idx;
}

int main(void)
{
  shmem_init();
  const int mype = shmem_my_pe();
  const int npes = shmem_n_pes();

  long *wait_vars = shmem_calloc(npes, sizeof(long));
  if (mype == 0)
  {
    int who = user_wait_any(wait_vars, npes, SHMEM_CMP_NE, 0);
    printf("PE %d observed first update from PE %d\n", mype, who);
  }
  else
    shmem_p(&wait_vars[mype], mype, 0);

  shmem_free(wait_vars);
  shmem_finalize();
  return 0;
}
```

10.11 Memory Ordering Routines

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

10.11.1 SHMEM_FENCE

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

SYNOPSIS

> **C/C++:**
> ```
> void shmem_fence(void);
> void shmem_ctx_fence(shmem_ctx_t ctx);
> ```
> — deprecation start ——
> **FORTRAN:**
> ```
> CALL SHMEM_FENCE
> ```
> —— deprecation end —

DESCRIPTION

> **Arguments**
>> **IN**   *ctx*   A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.

> **API description**

>> This routine assures ordering of delivery of *Put*, AMO, memory store, and nonblocking *Put* routines to symmetric data objects. All *Put*, AMO, memory store, and nonblocking *Put* routines to symmetric data objects issued to a particular remote PE on the given context prior to the call to *shmem_fence* are guaranteed to be delivered before any subsequent *Put*, AMO, memory store, and nonblocking *Put* routines to symmetric data objects to the same PE. *shmem_fence* guarantees order of delivery, not completion. It does not guarantee order of delivery of nonblocking *Get* routines. If *ctx* has the value *SHMEM_CTX_INVALID*, no operation is performed.

> **Return Values**
>> None.

> **Notes**
>> *shmem_fence* only provides per-PE ordering guarantees and does not guarantee completion of delivery. *shmem_fence* also does not have an effect on the ordering between memory accesses issued by the target PE. *shmem_wait_until*, *shmem_test*, *shmem_barrier*, *shmem_barrier_all* routines can be called by the target PE to guarantee ordering of its memory accesses. There is a subtle difference between *shmem_fence* and *shmem_quiet*, in that, *shmem_quiet* guarantees completion of *Put*, AMO, memory store, and nonblocking *Put* 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*, AMO, memory store, and nonblocking *Put* routines to symmetric data objects is desired when multiple remote PEs are involved.
>> In an OpenSHMEM program with multithreaded PEs, it is the user's responsibility to ensure ordering between operations issued by the threads in a PE that target symmetric memory (e.g. *Put*, AMO, memory

stores, and nonblocking routines) and calls by threads in that PE to *shmem_fence*. The *shmem_fence* routine can enforce memory store ordering only for the calling thread. Thus, to ensure ordering for memory stores performed by a thread that is not the thread calling *shmem_fence*, the update must be made visible to the calling thread according to the rules of the memory model associated with the threading environment.

EXAMPLES

The following example uses *shmem_fence* in a *C11* program:

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

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

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

10.11.2 SHMEM_QUIET

Waits for completion of all outstanding *Put*, AMO, memory store, and nonblocking *Put* and *Get* routines to symmetric data objects issued by a PE.

SYNOPSIS

C/C++:
```c
void shmem_quiet(void);
void shmem_ctx_quiet(shmem_ctx_t ctx);
```
— deprecation start —
FORTRAN:
```fortran
CALL SHMEM_QUIET
```
—— deprecation end —

DESCRIPTION

Arguments

IN	*ctx*	A context handle specifying the context on which to perform the operation. When this argument is not provided, the operation is performed on the default context.

API description

The *shmem_quiet* routine ensures completion of *Put*, AMO, memory store, and nonblocking *Put* and *Get* routines on symmetric data objects issued by the calling PE on the given context. All *Put*, AMO, memory store, and nonblocking *Put* and *Get* routines to symmetric data objects are guaranteed to be completed and visible to all PEs when *shmem_quiet* returns. If *ctx* has the value *SHMEM_CTX_INVALID*, no operation is performed.

Return Values

None.

Notes

shmem_quiet is most useful as a way of ensuring completion of several *Put*, AMO, memory store, and nonblocking *Put* and *Get* routines to symmetric data objects initiated by the calling PE. For example, one might use *shmem_quiet* to await delivery of a block of data before issuing another *Put* or nonblocking *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.

In an OpenSHMEM program with multithreaded PEs, it is the user's responsibility to ensure ordering between operations issued by the threads in a PE that target symmetric memory (e.g. *Put*, AMO, memory stores, and nonblocking routines) and calls by threads in that PE to *shmem_quiet*. The *shmem_quiet* routine can enforce memory store ordering only for the calling thread. Thus, to ensure ordering for memory stores performed by a thread that is not the thread calling *shmem_quiet*, the update must be made visible to the calling thread according to the rules of the memory model associated with the threading environment.

A call to *shmem_quiet* by a thread completes the operations posted prior to calling *shmem_quiet*. If the user intends to also complete operations issued by a thread that is not the thread calling *shmem_quiet*, the user must ensure that the operations are performed prior to the call to *shmem_quiet*. This may require the use of a synchronization operation provided by the threading package. For example, when using POSIX Threads, the user may call the *pthread_barrier_wait* routine to ensure that all threads have issued operations before a thread calls *shmem_quiet*.

shmem_quiet does not have an effect on the ordering between memory accesses issued by the target PE. *shmem_wait_until*, *shmem_test*, *shmem_barrier*, *shmem_barrier_all* routines can be called by the target PE to guarantee ordering of its memory accesses.

EXAMPLES

The following example uses *shmem_quiet* in a *C11* program:

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

int main(void)
{
    static long dest[3];
    static long source[3] = { 1, 2, 3 };
    static int targ;
    static int src = 90;
    long x[3] = { 0 };
    int y = 0;
    shmem_init();
    int me = shmem_my_pe();
    if (me == 0) {
        shmem_put(dest, source, 3, 1); /* put1 */
        shmem_put(&targ, &src, 1, 2);  /* put2 */
        shmem_quiet();
```
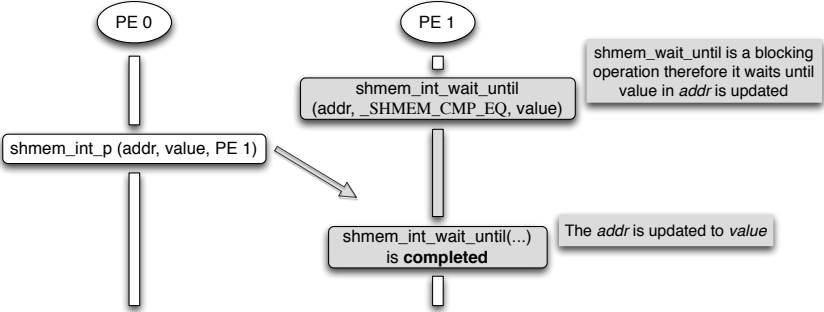
```
    shmem_get(x, dest, 3, 1);   /* gets updated value from dest on PE 1 to local array x */
    shmem_get(&y, &targ, 1, 2); /* gets updated value from targ on PE 2 to local variable
  y */
    printf("x: { %ld, %ld, %ld }\n", x[0], x[1], x[2]); /* x: { 1, 2, 3 } */
    printf("y: %d\n", y); /* y: 90 */
    shmem_put(&targ, &src, 1, 1); /* put3 */
    shmem_put(&targ, &src, 1, 2); /* put4 */
  }
  shmem_finalize();
  return 0;
}
```

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

10.11.3 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, stores, and nonblocking *Put* and *Get* routines on symmetric data cannot be guaranteed until some form of synchronization or ordering is introduced in the user's program. The table below gives the different synchronization and ordering choices, and the situations where they may be useful.

OpenSHMEM API	Working of OpenSHMEM API
Point-to-point synchronization *shmem_wait_until*	
	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.

Ordering puts issued by
a local PE
shmem_fence
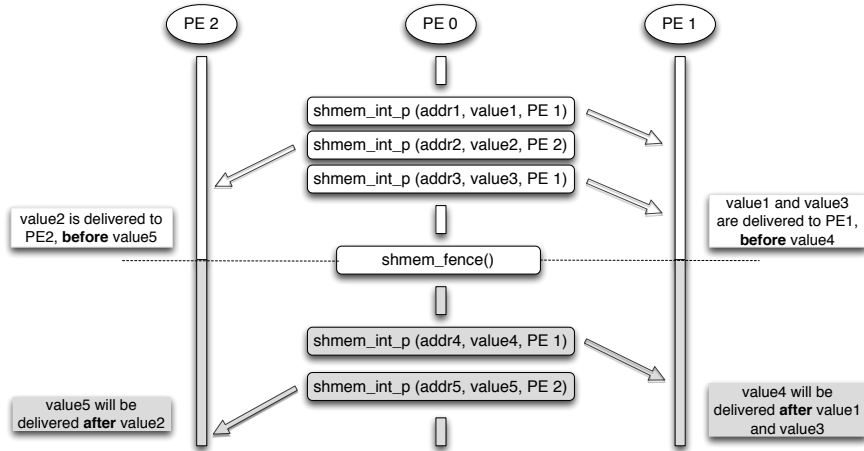
All *Put*, AMO, store, and nonblocking *Put* routines on symmetric data issued to same PE are guaranteed to be delivered before Puts (to the same PE) issued after the *fence* call.

OpenSHMEM API	Working of OpenSHMEM API

Ordering puts issued by
all PE
shmem_quiet
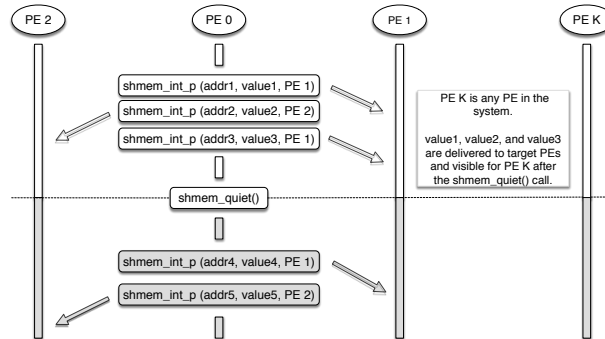
All *Put*, AMO, store, and nonblocking *Put* and *Get* routines on symmetric data issued by a local PE to all remote PEs are guaranteed to be completed and visible once quiet returns. This routine should be used when all remote writes issued by a local PE need to be visible to all other PEs before the local PE proceeds.

Collective synchroniza-
tion over an active set
shmem_barrier

PE 2   PE 0   PE 1   PE K

shmem_long_fadd(...)
shmem_int_p (...)
shmem_int_add (...)
shmem_int_get (...)

shmem_long_put(…)

shmem_int_p (...)

shmem_barrier(...)   shmem_barrier(...)   shmem_barrier(...)

All local and remote memory operations issued by PEs are guaranteed to be completed before any PE returns from the call.

shmem_int_get (...)

shmem_int_p (...)

shmem_long_p (...)

shmem_int_p (...)

shmem_long_put(…)
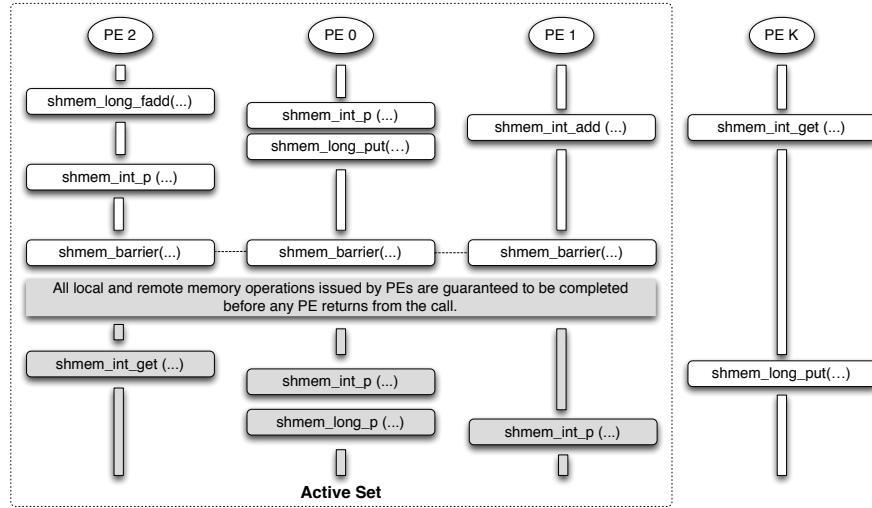
Active Set

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 shall return from the 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.

OpenSHMEM API	Working of OpenSHMEM API

Collective synchroniza-
tion over all PEs
shmem_barrier_all

PE 2   PE 0   PE 1   PE K

shmem_long_fadd(...)
shmem_int_p (...)
shmem_int_add (...)
shmem_int_get (...)

shmem_long_put(…)

shmem_int_p (...)

shmem_barrier_all(…)   shmem_barrier_all(…)   shmem_barrier_all(…)   ● ● ●   shmem_barrier_all(…)

All local and remote memory operations issued by PEs are guaranteed to be completed before any PE returns from the call.

shmem_int_get (...)

shmem_int_p (...)

shmem_long_p (...)

shmem_long_p (...)

shmem_int_p (...)
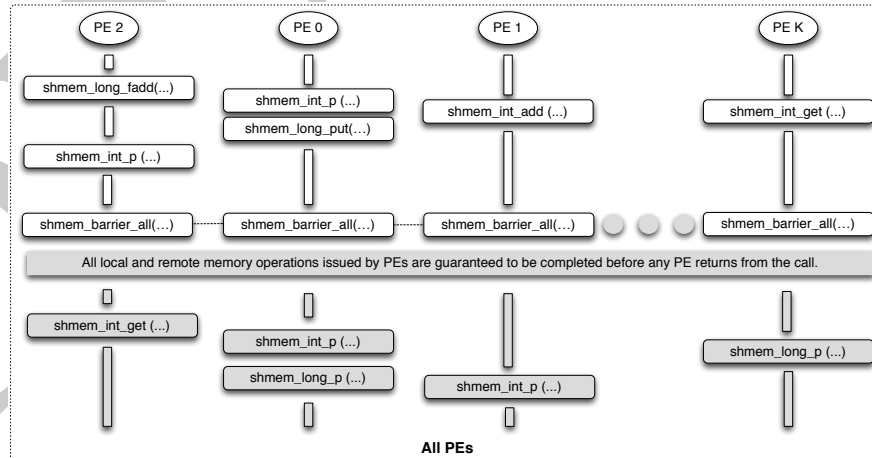
All PEs

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.

10.12   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*.

10.12.1   SHMEM_LOCK

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

SYNOPSIS

> **C/C++:**
> ```
> void shmem_clear_lock(long *lock);
> void shmem_set_lock(long *lock);
> int shmem_test_lock(long *lock);
> ```
> —— deprecation start ——
> **FORTRAN:**
> ```
> INTEGER lock, SHMEM_TEST_LOCK
> CALL SHMEM_CLEAR_LOCK(lock)
> CALL SHMEM_SET_LOCK(lock)
> I = SHMEM_TEST_LOCK(lock)
> ```
> ——— deprecation end ——

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*. When 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_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. The *shmem_clear_lock* routine releases a lock previously set by *shmem_set_lock* or *shmem_test_lock* after performing a quiet operation on the default context to ensure that all symmetric memory accesses that occurred during the critical region are complete. These routines are appropriate for protecting a critical region from simultaneous update by multiple PEs.
>>
>> The OpenSHMEM lock API provides a non-reentrant mutex. Thus, a call to *shmem_set_lock* or *shmem_test_lock* when the calling PE already holds the given lock will result in undefined behavior. In a multithreaded OpenSHMEM program, the user must ensure that such calls do not occur.
>
> **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 must be initialized to zero before any PE performs an OpenSHMEM lock operation on the given variable. Accessing an in-use lock variable using any method other than the OpenSHMEM lock API, e.g. using local load/store, RMA, or AMO operations, results in undefined behavior.

Calls to *shmem_ctx_quiet* can be performed prior to calling the *shmem_clear_lock* routine to ensure completion of operations issued on additional contexts.

EXAMPLES

The following example uses *shmem_lock* in a *C11* program.

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

int main(void)
{
    static long lock = 0;
    static int count = 0;
    shmem_init();
    int me = shmem_my_pe();
    shmem_set_lock(&lock);
    int val = shmem_g(&count, 0); /* get count value on PE 0 */
    printf("%d: count is %d\n", me, val);
    val++; /* incrementing and updating count on PE 0 */
    shmem_p(&count, val, 0);
    shmem_clear_lock(&lock); /* ensures count update has completed before clearing the lock */
    shmem_finalize();
    return 0;
}
```

10.13 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.

10.13.1 SHMEM_CACHE

Controls data cache utilities.

SYNOPSIS

— deprecation start —

C/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);
```

——————————————————————————————————— deprecation end —

— deprecation start —
FORTRAN:
```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. When 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

The following section describes how to write a "Hello World" OpenSHMEM program. To write a "Hello World" OpenSHMEM program, the user must:

- Include the header file *shmem.h* for *C* or *shmem.fh* for *Fortran*.

- Add the initialization call *shmem_init*.

- Use OpenSHMEM calls to query the local PE number (*shmem_my_pe*) and the total number of PEs (*shmem_n_pes*).

- Add the finalization call *shmem_finalize*.

In OpenSHMEM, the order in which lines appear in the output is not deterministic because PEs execute asynchronously in parallel.

Listing A.1: "Hello World" example program in *C*

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

Listing A.2: Possible ordering of expected output with 4 PEs from the program in Listing A.1

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

—— deprecation start ——

OpenSHMEM also provides a *Fortran* API. Listing A.3 shows a similar program written in *Fortran*.

Listing A.3: "Hello World" example program in *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.4: Possible ordering of expected output with 4 PEs from the program in Listing A.3

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

—— deprecation end ——

The example in Listing A.5 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 *shmem_put*.

The *static* keyword makes the *dest* array symmetric on all PEs. Each PE is able to transfer data to a remote *dest* array by simply specifying to an OpenSHMEM routine such as *shmem_put* the local address of the symmetric data object that will receive the data. This local address resolution aids programmability because the address of the *dest* need not be exchanged with the active side (PE *0*) prior to the *Remote Memory Access* (RMA) routine.

Conversely, the declaration of the *short source* array is asymmetric (local only). The *source* object does not need to be symmetric because *Put* handles the references to the *source* array only on the active (local) side.

Listing A.5: Example program with symmetric data objects

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

#define SIZE 16

int main(void)
{
    short source[SIZE];
    static short dest[SIZE];
    static long lock = 0;
    shmem_init();
    int me = shmem_my_pe();
    int npes = shmem_n_pes();
    if (me == 0) {
        /* initialize array */
        for (int i = 0; i < SIZE; i++)
            source[i] = i;
        /* local, not symmetric */
        /* static makes it symmetric */
        /* put "size" words into dest on each PE */
        for (int i = 1; i < npes; i++)
            shmem_put(dest, source, SIZE, i);
    }
    shmem_barrier_all(); /* sync sender and receiver */
    if (me != 0) {
        shmem_set_lock(&lock);
        printf("dest on PE %d is \t", me);
        for (int i = 0; i < SIZE; i++)
            printf("%hd \t", dest[i]);
        printf("\n");
        shmem_clear_lock(&lock);
    }
    shmem_finalize();
    return 0;
}
```

Listing A.6: Possible ordering of expected output with 4 PEs from the program in Listing A.5

```
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

The OpenSHMEM Specification does not specify 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 may be called as follows:

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

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

Programs written in *C++*

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

```
oshc++ <compiler options> -o myprogram myprogram.cpp
```

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

Programs written in *Fortran*

— deprecation start ———

The OpenSHMEM Reference Implementation provides a wrapper program, named **oshfort**, to aid in the compilation of *Fortran* programs. The wrapper may 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**.

—— deprecation end —

2   Running Programs

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

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

The arguments for **oshrun** are:

⟨runner 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 OpenSHMEM Specification formalizes the expected behavior of its library routines. In cases where routines are improperly used or the input is not in accordance with the Specification, the behavior is undefined.

Inappropriate Usage	Undefined Behavior
Uninitialized library	If the OpenSHMEM library is not initialized, calls to non-initializing OpenSHMEM routines have undefined behavior. For example, an implementation may try to continue or may abort immediately upon an OpenSHMEM call into the uninitialized library.
Multiple calls to initialization routines	In an OpenSHMEM program where the initialization routines *shmem_init* or *shmem_init_thread* have already been called, any subsequent calls to these initialization routines result in undefined behavior.
Accessing non-existent PEs	If a communications routine accesses a non-existent PE, then the OpenSHMEM library may handle this situation in an implementation-defined way. For example, the library may report 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. For example, a *Put* to a non-symmetric variable may be trapped where possible and the library may abort the program. Another implementation may choose to continue execution with or without a warning.
Non-symmetric allocation of symmetric memory	The symmetric memory management routines are collectives. For example, all PEs in the program must call *shmem_malloc* with the same *size* argument. 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, a null pointer may not be given 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 non-null: supported. • *len* is not 0, pointer is non-null: supported.

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Annex D

History of OpenSHMEM

SHMEM has a long history as a parallel-programming model and has been extensively used on a number of products since 1993, including the Cray T3D, Cray X1E, Cray XT3 and XT4, Silicon Graphics International (SGI) Origin, SGI Altix, Quadrics-based clusters, and InfiniBand-based clusters.

- SHMEM Timeline

    - Cray SHMEM

        * SHMEM first introduced by Cray Research, Inc. in 1993 for Cray T3D
        * Cray was acquired by SGI in 1996
        * Cray was acquired by Tera in 2000 (MTA)
        * Platforms: Cray T3D, T3E, C90, J90, SV1, SV2, X1, X2, XE, XMT, XT

    - SGI SHMEM

        * SGI acquired 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 acquired by Rackable Systems in 2009
        * SGI and OSSS signed a SHMEM trademark licensing agreement in 2010
        * HPE acquired SGI in 2016

A listing of OpenSHMEM implementations can be found on http://www.openshmem.org/.

Annex E

OpenSHMEM Specification and Deprecated API

1 Overview

For the OpenSHMEM Specification, deprecation is the process of identifying API that is supported but no longer recommended for use by users. The deprecated API **must** be supported until clearly indicated as otherwise by the Specification. This chapter records the API or functionality that have been deprecated, the version of the OpenSHMEM Specification that effected the deprecation, and the most recent version of the OpenSHMEM Specification in which the feature was supported before removal.

Deprecated API	Deprecated Since	Last Version Supported	Replaced By
Header Directory: *mpp*	1.1	Current	(none)
C/C++: *start_pes*	1.2	Current	*shmem_init*
Fortran: *START_PES*	1.2	Current	*SHMEM_INIT*
Implicit finalization	1.2	Current	*shmem_finalize*
C/C++: *_my_pe*	1.2	Current	*shmem_my_pe*
C/C++: *_num_pes*	1.2	Current	*shmem_n_pes*
Fortran: *MY_PE*	1.2	Current	*SHMEM_MY_PE*
Fortran: *NUM_PES*	1.2	Current	*SHMEM_N_PES*
C/C++: *shmalloc*	1.2	Current	*shmem_malloc*
C/C++: *shfree*	1.2	Current	*shmem_free*
C/C++: *shrealloc*	1.2	Current	*shmem_realloc*
C/C++: *shmemalign*	1.2	Current	*shmem_align*
Fortran: *SHMEM_PUT*	1.2	Current	*SHMEM_PUT8* or *SHMEM_PUT64*
C/C++: *shmem_clear_cache_inv* *Fortran*: *SHMEM_CLEAR_CACHE_INV*	1.3	Current	(none)
C/C++: *shmem_clear_cache_line_inv*	1.3	Current	(none)
C/C++: *shmem_set_cache_inv* *Fortran*: *SHMEM_SET_CACHE_INV*	1.3	Current	(none)
C/C++: *shmem_set_cache_line_inv* *Fortran*: *SHMEM_SET_CACHE_LINE_INV*	1.3	Current	(none)
C/C++: *shmem_udcflush* *Fortran*: *SHMEM_UDCFLUSH*	1.3	Current	(none)
C/C++: *shmem_udcflush_line* *Fortran*: *SHMEM_UDCFLUSH_LINE*	1.3	Current	(none)
_SHMEM_SYNC_VALUE	1.3	Current	*SHMEM_SYNC_VALUE*
_SHMEM_BARRIER_SYNC_SIZE	1.3	Current	*SHMEM_BARRIER_SYNC_SIZE*
_SHMEM_BCAST_SYNC_SIZE	1.3	Current	*SHMEM_BCAST_SYNC_SIZE*
_SHMEM_COLLECT_SYNC_SIZE	1.3	Current	*SHMEM_COLLECT_SYNC_SIZE*
_SHMEM_REDUCE_SYNC_SIZE	1.3	Current	*SHMEM_REDUCE_SYNC_SIZE*
_SHMEM_REDUCE_MIN_WRKDATA_SIZE	1.3	Current	*SHMEM_REDUCE_MIN_WRKDATA_SIZE*
_SHMEM_MAJOR_VERSION	1.3	Current	*SHMEM_MAJOR_VERSION*
_SHMEM_MINOR_VERSION	1.3	Current	*SHMEM_MINOR_VERSION*
_SHMEM_MAX_NAME_LEN	1.3	Current	*SHMEM_MAX_NAME_LEN*
_SHMEM_VENDOR_STRING	1.3	Current	*SHMEM_VENDOR_STRING*
_SHMEM_CMP_EQ	1.3	Current	*SHMEM_CMP_EQ*
_SHMEM_CMP_NE	1.3	Current	*SHMEM_CMP_NE*
_SHMEM_CMP_LT	1.3	Current	*SHMEM_CMP_LT*
_SHMEM_CMP_LE	1.3	Current	*SHMEM_CMP_LE*

Deprecated API	Deprecated Since	Last Version Supported	Replaced By
_SHMEM_CMP_GT	1.3	Current	SHMEM_CMP_GT
_SHMEM_CMP_GE	1.3	Current	SHMEM_CMP_GE
SMA_VERSION	1.4	Current	SHMEM_VERSION
SMA_INFO	1.4	Current	SHMEM_INFO
SMA_SYMMETRIC_SIZE	1.4	Current	SHMEM_SYMMETRIC_SIZE
SMA_DEBUG	1.4	Current	SHMEM_DEBUG
C/C++: shmem_wait C/C++: shmem_<**TYPENAME**>_wait	1.4	Current	See **Notes** for shmem_wait_until
C/C++: shmem_wait_until	1.4	Current	C11: shmem_wait_until, C/C++: shmem_long_wait_until
C11: shmem_fetch C/C++: shmem_<**TYPENAME**>_fetch	1.4	Current	shmem_atomic_fetch
C11: shmem_set C/C++: shmem_<**TYPENAME**>_set	1.4	Current	shmem_atomic_set
C11: shmem_cswap C/C++: shmem_<**TYPENAME**>_cswap	1.4	Current	shmem_atomic_compare_swap
C11: shmem_swap C/C++: shmem_<**TYPENAME**>_swap	1.4	Current	shmem_atomic_swap
C11: shmem_finc C/C++: shmem_<**TYPENAME**>_finc	1.4	Current	shmem_atomic_fetch_inc
C11: shmem_inc C/C++: shmem_<**TYPENAME**>_inc	1.4	Current	shmem_atomic_inc
C11: shmem_fadd C/C++: shmem_<**TYPENAME**>_fadd	1.4	Current	shmem_atomic_fetch_add
C11: shmem_add C/C++: shmem_<**TYPENAME**>_add	1.4	Current	shmem_atomic_add
Entire Fortran API	1.4	Current	(none)
All active-set-based collective routines	1.5	Current	Teams-based collective routines
C/C++: shmem_barrier	1.5	Current	shmem_quiet; shmem_team_sync
C/C++: shmem_barrier_all	1.5	Current	shmem_quiet; shmem_team_sync(SHMEM_TEAM_WORLD)
C/C++: shmem_sync_all	1.5	Current	shmem_team_sync(SHMEM_TEAM_WORLD)

2 Deprecation Rationale

2.1 Header Directory: *mpp*

In addition to the default system header paths, OpenSHMEM implementations must provide all OpenSHMEM-specified header files from the *mpp* header directory such that these headers can be referenced in *C/C++* as

```
#include <mpp/shmem.h>
#include <mpp/shmemx.h>
```

and in *Fortran* as

```
include 'mpp/shmem.fh'
include 'mpp/shmemx.fh'
```

for backwards compatibility with SGI SHMEM.

2.2 *C/C++*: *start_pes*

The *C/C++* routine *start_pes* includes an unnecessary initialization argument that is remnant of historical *SHMEM* implementations and no longer reflects the requirements of modern OpenSHMEM implementations. Furthermore, the naming of *start_pes* does not include the standardized *shmem_* naming prefix. This routine has been deprecated and OpenSHMEM users are encouraged to use *shmem_init* instead.

2.3 Implicit Finalization

Implicit finalization was deprecated and replaced with explicit finalization using the *shmem_finalize* routine. Explicit finalization improves portability and also improves interoperability with profiling and debugging tools.

2.4   *C/C++*: *_my_pe*, *_num_pes*, *shmalloc*, *shfree*, *shrealloc*, *shmemalign*

The *C/C++* routines *_my_pe*, *_num_pes*, *shmalloc*, *shfree*, *shrealloc*, and *shmemalign* were deprecated in order to normalize the OpenSHMEM API to use *shmem_* as the standard prefix for all routines.

2.5   *Fortran*: *START_PES*, *MY_PE*, *NUM_PES*

The *Fortran* routines *START_PES*, *MY_PE*, and *NUM_PES* were deprecated in order to minimize the API differences from the deprecation of *C/C++* routines *start_pes*, *_my_pe*, and *_num_pes*.

2.6   *Fortran*: *SHMEM_PUT*

The *Fortran* routine *SHMEM_PUT* is defined only for the *Fortran* API and is semantically identical to *Fortran* routines *SHMEM_PUT8* and *SHMEM_PUT64*. Since *SHMEM_PUT8* and *SHMEM_PUT64* have defined equivalents in the *C/C++* interface, *SHMEM_PUT* is ambiguous and has been deprecated.

2.7   SHMEM_CACHE

The *SHMEM_CACHE* API

C/C++:	*Fortran*:
shmem_clear_cache_inv	*SHMEM_CLEAR_CACHE_INV*
shmem_set_cache_inv	*SHMEM_SET_CACHE_INV*
shmem_set_cache_line_inv	*SHMEM_SET_CACHE_LINE_INV*
shmem_udcflush	*SHMEM_UDCFLUSH*
shmem_udcflush_line	*SHMEM_UDCFLUSH_LINE*
shmem_clear_cache_line_inv	

was originally implemented for systems with cache-management instructions. This API has largely gone unused on cache-coherent system architectures. *SHMEM_CACHE* has been deprecated.

2.8   *_SHMEM_*** Library Constants

The library constants

_SHMEM_SYNC_VALUE	*_SHMEM_MAX_NAME_LEN*
_SHMEM_BARRIER_SYNC_SIZE	*_SHMEM_VENDOR_STRING*
_SHMEM_BCAST_SYNC_SIZE	*_SHMEM_CMP_EQ*
_SHMEM_COLLECT_SYNC_SIZE	*_SHMEM_CMP_NE*
_SHMEM_REDUCE_SYNC_SIZE	*_SHMEM_CMP_LT*
_SHMEM_REDUCE_MIN_WRKDATA_SIZE	*_SHMEM_CMP_LE*
_SHMEM_MAJOR_VERSION	*_SHMEM_CMP_GT*
_SHMEM_MINOR_VERSION	*_SHMEM_CMP_GE*

do not adhere to the *C* standard's reserved identifiers and the *C++* standard's reserved names. These constants were deprecated and replaced with corresponding constants of prefix *SHMEM_* that adhere to *C/C++* and *Fortran* naming conventions.

2.9   *SMA_*** Environment Variables

The environment variables *SMA_VERSION*, *SMA_INFO*, *SMA_SYMMETRIC_SIZE*, and *SMA_DEBUG* were deprecated in order to normalize the OpenSHMEM API to use *SHMEM_* as the standard prefix for all environment variables.

2.10 *C/C++*: *shmem_wait*

The *C/C++* interface for *shmem_wait* and *shmem_<TYPENAME>_wait* was identified as unintuitive with respect to the comparison operation it performed. As *shmem_wait* can be trivially replaced by *shmem_wait_until* where *cmp* is *SHMEM_CMP_NE*, the *shmem_wait* interface was deprecated in favor of *shmem_wait_until*, which makes the comparison operation explicit and better communicates the developer's intent.

2.11 *C/C++*: *shmem_wait_until*

The *long*-typed *C/C++* routine *shmem_wait_until* was deprecated in favor of the *C11* type-generic interface of the same name or the explicitly typed *C/C++* routine *shmem_long_wait_until*.

2.12 *C11* and *C/C++*: *shmem_fetch*, *shmem_set*, *shmem_cswap*, *shmem_swap*, *shmem_finc*, *shmem_inc*, *shmem_fadd*, *shmem_add*

The *C11* and *C/C++* interfaces for

C11:	*C/C++*:
shmem_fetch	*shmem_<TYPENAME>_fetch*
shmem_set	*shmem_<TYPENAME>_set*
shmem_cswap	*shmem_<TYPENAME>_cswap*
shmem_swap	*shmem_<TYPENAME>_swap*
shmem_finc	*shmem_<TYPENAME>_finc*
shmem_inc	*shmem_<TYPENAME>_inc*
shmem_fadd	*shmem_<TYPENAME>_fadd*
shmem_add	*shmem_<TYPENAME>_add*

were deprecated and replaced with similarly named interfaces within the *shmem_atomic_** namespace in order to more clearly identify these calls as performing atomic operations. In addition, the abbreviated names "cswap", "finc", and "fadd" were expanded for clarity to "compare_swap", "fetch_inc", and "fetch_add".

2.13 *Fortran* API

The entire OpenSHMEM *Fortran* API was deprecated because of a general lack of use and a lack of conformance with legacy *Fortran* standards. In lieu of an extensive update of the *Fortran* API, *Fortran* users are encouraged to leverage the OpenSHMEM Specification's *C* API through the *Fortran–C* interoperability initially standardized by *Fortran 2003*[1].

2.14 Active-set-based collective routines

With the addition of OpenSHMEM teams, the previous methods for performing collective operations has been superseded by a more readable, flexible method for organizing and communicating between groups of PEs. All collective routines which previously indicated subgroups of PEs with a list of parameters to describe the subgroup composition should be phased out in favor of using collective operations with a team parameter.

When moving from active set routines to teams based routines, the fixed-size versions of the routines, e.g. *shmem_broadcast32*, were not carried forward. Instead, all teams based collective routines use standard *C* types with the option to use generic *C11* functions for more portable and maintainable implementations.

2.15 *C/C++*: *shmem_barrier*

Each OpenSHMEM team might be associated with some number of communication contexts. The *shmem_barrier* functions imply that the default context is quiesced after synchronizing some set of PEs. Since teams may have some

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[1] Formally, *Fortran 2003* is known as ISO/IEC 1539-1:2004(E).

number of contexts associated with the team, it becomes less clear which context would be the "default" context for that particular team. Rather than continue to support *shmem_barrier* for active-sets or teams, programs should use a call to *shmem_quiet* followed by a call to *shmem_sync* in order to explicitly indicate which context to quiesce.

2.16   *C/C++*: *shmem_barrier_all*, *shmem_sync_all*

With the addition of OpenSHMEM teams combined, the notion of all PEs has been encapsulated as *SHMEM_TEAM_WORLD*. The previous method of specifying active sets to *shmem_barrier* and *shmem_sync* was verbose. So, shorthand versions of these functions were helpful both in readability and ability to improve performance by not requiring tests of active set parameters to determine that the routine involved all PEs. With teams, becomes readable in a program to simply call a barrier or sync on *SHMEM_TEAM_WORLD*. Implementations need only test one constant to determine that the operation involves all PEs.

Annex F

Changes to this Document

1 Version 1.5

Major changes in OpenSHMEM 1.5 include . . .

The following list describes the specific changes in OpenSHMEM 1.5:

- Specified the validity of communication contexts, added the constant *SHMEM_CTX_INVALID*, and clarified the behavior of *shmem_ctx_** routines on invalid contexts.
  See Section 10.5.

- Clarified PE active set requirements.
  See Section 10.9.

- Clarified that when the *size* argument is zero, symmetric heap allocation routines perform no action and return a null pointer; that symmetric heap management routines that perform no action do not perform a barrier; and that the *alignment* argument to *shmem_align* must be power of two multiple of *sizeof(void*)*.
  See Section 10.3.1.

- Clarified that the OpenSHMEM lock API provides a non-reentrant mutex and that *shmem_clear_lock* performs a quiet operation on the default context.
  See Section 10.12.1

- Clarified the atomicity guarantees of the OpenSHMEM memory model.
  See Section 3.1.

2 Version 1.4

Major changes in OpenSHMEM 1.4 include multithreading support, *contexts* for communication management, *shmem_sync*, *shmem_calloc*, expanded type support, a new namespace for atomic operations, atomic bitwise operations, *shmem_test* for nonblocking point-to-point synchronization, and *C11* type-generic interfaces for point-to-point synchronization.

The following list describes the specific changes in OpenSHMEM 1.4:

- New communication management API, including *shmem_ctx_create*; *shmem_ctx_destroy*; and additional RMA, AMO, and memory ordering routines that accept *shmem_ctx_t* arguments.
  See Section 10.5.

- New API *shmem_sync_all* and *shmem_sync* to provide PE synchronization without completing pending communication operations.
  See Sections 10.9.4 and 10.9.3.

- Clarified that the OpenSHMEM extensions header files are required, even when empty.
  See Section 5.

- Clarified that the *SHMEM_GET64* and *SHMEM_GET64_NBI* routines are included in the *Fortran* language
  bindings.
  See Sections 10.6.4 and 10.7.2.

- Clarified that *shmem_init* must be matched with a call to *shmem_finalize*.
  See Sections 10.1.1 and 10.1.4.

- Added the *SHMEM_SYNC_SIZE* constant.
  See Section 6.

- Added type-generic interfaces for *shmem_wait_until*.
  See Section 10.10.1.

- Removed the *volatile* qualifiers from the *ivar* arguments to *shmem_wait* routines and the *lock* arguments in the
  lock API. *Rationale: Volatile qualifiers were added to several API routines in OpenSHMEM 1.3; however, they
  were later found to be unnecessary.*
  See Sections 10.10.1 and 10.12.1.

- Deprecated the *SMA_** environment variables and added equivalent *SHMEM_** environment variables.
  See Section 8.

- Added the *C11 _Noreturn* function specifier to *shmem_global_exit*.
  See Section 10.1.5.

- Clarified ordering semantics of memory ordering, point-to-point synchronization, and collective synchronization
  routines.

- Clarified deprecation overview and added deprecation rationale in Annex F.
  See Section E.

- Deprecated header directory *mpp*.
  See Section E.

- Deprecated the *shmem_wait* functions and the *long*-typed *C/C++ shmem_wait_until* function.
  See Section 10.10.

- Added the *shmem_test* functions.
  See Section 10.10.

- Added the *shmem_calloc* function.
  See Section 10.3.2.

- Introduced the thread safe semantics that define the interaction between OpenSHMEM routines and user threads.
  See Section 10.2.

- Added the new routine *shmem_init_thread* to initialize the OpenSHMEM library with one of the defined thread
  levels.
  See Section 10.2.1.

- Added the new routine *shmem_query_thread* to query the thread level provided by the OpenSHMEM imple-
  mentation.
  See Section 10.2.2.

- Clarified the semantics of *shmem_quiet* for a multithreaded OpenSHMEM PE.
  See Section 10.11.2

- Revised the description of *shmem_barrier_all* for a multithreaded OpenSHMEM PE.
  See Section 10.9.1

- Revised the description of *shmem_wait* for a multithreaded OpenSHMEM PE.
  See Section 10.10.1

- Clarified description for *SHMEM_VENDOR_STRING*.
  See Section 6.

- Clarified description for *SHMEM_MAX_NAME_LEN*.
  See Section 6.

- Clarified API description for *shmem_info_get_name*.
  See Section 10.1.10.

- Expanded the type support for RMA, AMO, and point-to-point synchronization operations.
  See Tables 3, 4, 5, and 8

- Renamed AMO operations to use *shmem_atomic_* * prefix and deprecated old AMO routines.
  See Section 10.8.

- Added fetching and non-fetching bitwise AND, OR, and XOR atomic operations.
  See Section 10.8.

- Deprecated the entire *Fortran* API.

- Replaced the *complex* macro in complex-typed reductions with the *C99* (and later) type specifier *_Complex* to
  remove an implicit dependence on *complex.h*.
  See Section 10.9.7.

- Clarified that complex-typed reductions in C are optionally supported.
  See Section 10.9.7.

3   Version 1.3

Major changes in OpenSHMEM 1.3 include the addition of nonblocking RMA operations, atomic *Put* and *Get* operations, all-to-all collectives, and *C11* type-generic interfaces for RMA and AMO operations.

The following list describes the specific changes in OpenSHMEM 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 3.1.

- 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 10.6, 10.7 and 10.8.

- New nonblocking variants of remote memory access, *SHMEM_PUT_NBI* and *SHMEM_GET_NBI*.
  See Sections 10.7.1 and 10.7.2.

- New atomic elemental read and write operations, *SHMEM_FETCH* and *SHMEM_SET*.
  See Sections 10.8.1 and 10.8.2

- New alltoall data exchange operations, *SHMEM_ALLTOALL* and *SHMEM_ALLTOALLS*.
  See Sections 10.9.8 and 10.9.9.

- Added *volatile* to remotely accessible pointer argument in *SHMEM_WAIT* and *SHMEM_LOCK*.
  See Sections 10.10.1 and 10.12.1.

- Deprecation of *SHMEM_CACHE*.
  See Section 10.13.1.

4   Version 1.2

Major changes in OpenSHMEM 1.2 include a new initialization routine (*shmem_init*), improvements to the execution model with an explicit library-finalization routine (*shmem_finalize*), an early-exit routine (*shmem_global_exit*), namespace standardization, and clarifications to several API descriptions.

The following list describes the specific changes in OpenSHMEM 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*'s *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 10.1.1.

- Deprecation of *_my_pe* and *_num_pes* routines.
  See Sections 10.1.2 and 10.1.3.

- New API *shmem_finalize* to provide collective mechanism to cleanly exit an OpenSHMEM program and release resources.
  See Section 10.1.4.

- New API *shmem_global_exit* to provide mechanism to exit an OpenSHMEM program.
  See Section 10.1.5.

- Clarification related to the address of the referenced object in *shmem_ptr*.
  See Section 10.1.8.

- New API to query the version and name information.
  See Section 10.1.9 and 10.1.10.

- OpenSHMEM library API normalization. All *C* symmetric memory management API begins with *shmem_*.
  See Section 10.3.1.

- Notes and clarifications added to *shmem_malloc*.
  See Section 10.3.1.

- Deprecation of *Fortran* API routine *SHMEM_PUT*.
  See Section 10.6.1.

- Clarification related to *shmem_wait*.
  See Section 10.10.1.

- Undefined behavior for null pointers without zero counts added.
  See Annex C

- Addition of new Annex for clearly specifying deprecated API and its support across versions of the Open-SHMEM Specification.
  See Annex E.

5   Version 1.1

Major changes from OpenSHMEM 1.0 to OpenSHMEM 1.1 include the introduction of the *shmemx.h* header file for non-standard API extensions, clarifications to completion semantics and API descriptions in agreement with the SGI SHMEM specification, and general readabilty and usability improvements to the document structure.

The following list describes the specific changes in OpenSHMEM 1.1:

- Clarifications of the completion semantics of memory synchronization interfaces.
  See Section 10.11.

- Clarification of the completion semantics of memory load and store operations in context of *shmem_barrier_all* and *shmem_barrier* routines.
  See Section 10.9.1 and 10.9.2.

- Clarification of the completion and ordering semantics of *shmem_quiet* and *shmem_fence*.
  See Section 10.11.2 and 10.11.1.

- Clarifications of the completion semantics of RMA and AMO routines.
  See Sections 10.6 and 10.8

- 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 10.1.6 and 10.1.7.

- Added an annex on interoperability with MPI.
  See Annex **??**.

- Added examples to the different interfaces.

- Clarification of the naming conventions for constant in *C* and *Fortran*.
  See Section 6 and 10.10.1.

- Added API calls: *shmem_char_p*, *shmem_char_g*.
  See Sections 10.6.2 and 10.6.5.

- Removed API calls: *shmem_char_put*, *shmem_char_get*.
  See Sections 10.6.1 and 10.6.4.

- The usage of *ptrdiff_t*, *size_t*, and *int* in the interface signature was made consistent with the description.
  See Sections 10.9, 10.6.3, and 10.6.6.

- Revised *shmem_barrier* example.
  See Section 10.9.2.

- Clarification of the initial value of *pSync* work arrays for *shmem_barrier*.
  See Section 10.9.2.

- Clarification of the expected behavior when multiple *start_pes* calls are encountered.
  See Section 10.1.11.

- Corrected the definition of atomic increment operation.
  See Section 10.8.6.

- Clarification of the size of the symmetric heap and when it is set.
  See Section 10.3.1.

- Clarification of the integer and real sizes for *Fortran* API.
  See Sections 10.8.8, 10.8.3, 10.8.4, 10.8.5, 10.8.6, and 10.8.7.

- 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 10.3.1 and Annex C.

- *Fortran* programming fixes for examples.
  See Sections 10.9.7 and 10.10.1.

- Clarifications of the reuse *pSync* and *pWork* across collectives.
  See Sections 10.9, 10.9.5, 10.9.6 and 10.9.7.

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

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