OpenSHMEM Workshop 2015

Check-pointing approach for fault tolerance in OpenSHMEM

Pengfei Hao
Pavel Shamis,
Swaroop Pophale,
Tony Curtis,
Barbara Chapman

Fault Tolerance

Necessary:

- HPC system consist more components than before.
- Mean Time To Failure(MTTF) of individual components failed to increase.

Previous Related Work

N.Ali, S.Krishnamoorthy, N.Govind, and B.Palmer. **A redundant communication approach to scalable fault tolerance in PGAS programming models.** In *Parallel Distributed and Network-Based Processing(PDP) , 2011 19th Euromicro International Conference*.

Limitation:

- Algorithm specific solution. “Maintaining and continuously updating shadow data structures.”
- Manually effort to manage backup and checkpoint restore

Previous Related Work

Hao, Pengfei, et al. **Fault Tolerance for OpenSHMEM**. *Proceedings of the 8th International Conference on Partitioned Global Address Space Programming Models. ACM, 2014*.

Goal:

- Unified Model for fault tolerance
- Unified API for check-pointing, restore.

Design target

Fault mitigation. Not fault detector.
Assuming exist a perfect fault detector.

OpenSHMEM Memory Model

Symmetric Regions:

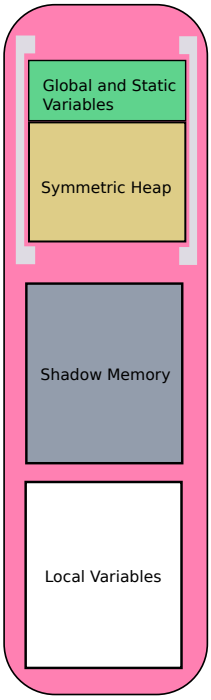
- Fortran data object in common blocks or with the SAVE attribute
- Global and Static C and C++ variables
- Fortran mem allocated by shpalloc()
- C and C++ mem allocated by shmalloc()

User need to store algorithm data in symmetric region.

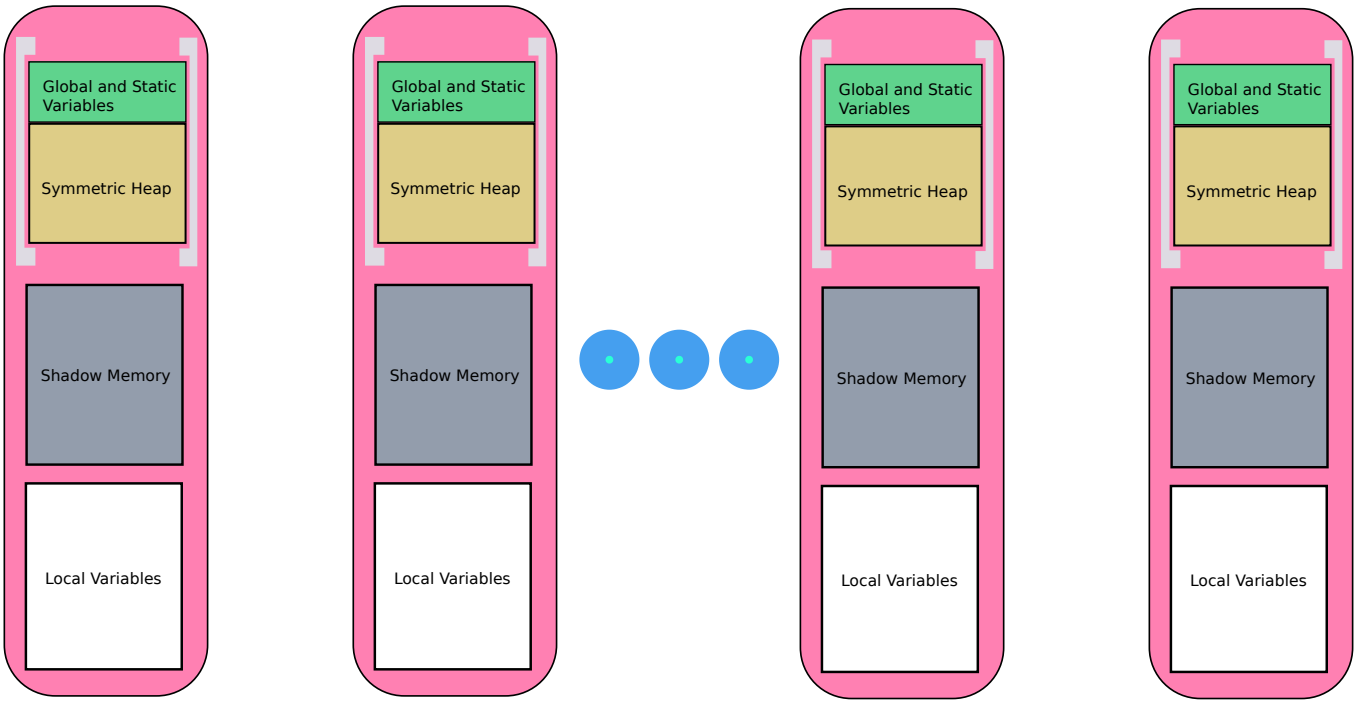
Fault tolerance Design

- User Level Fault Mitigation(ULFM)
  User need to call APIs to support the features.
- Backup all symmetric regions
  For ELF, BSS/DATA/HEAP
- Substitute PE capacity
  Spawn new or sleep as substitute
- Partner PE and shadow memory
  Multiple symmetric regions support

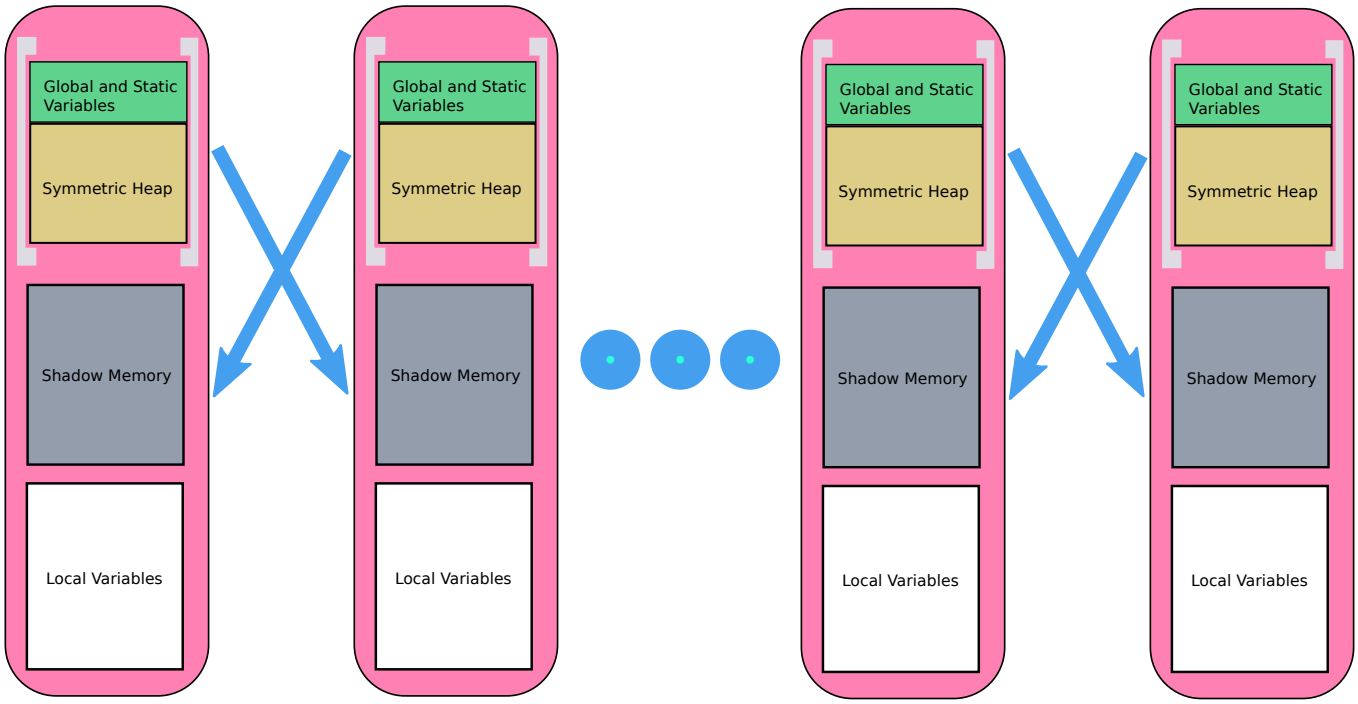
Fault tolerance Design - Memory Layout



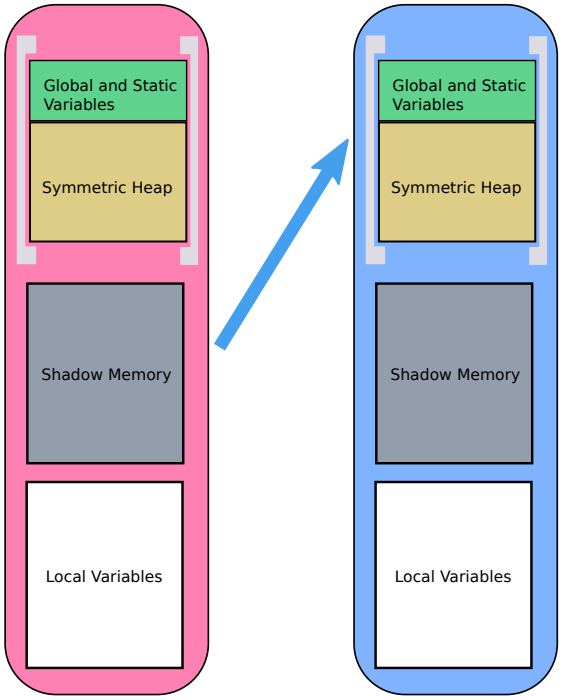
Fault tolerance Design - Backup



Fault tolerance Design - Backup



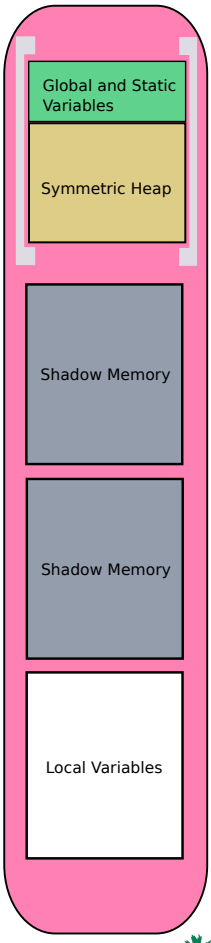
Fault tolerance Design - Restore



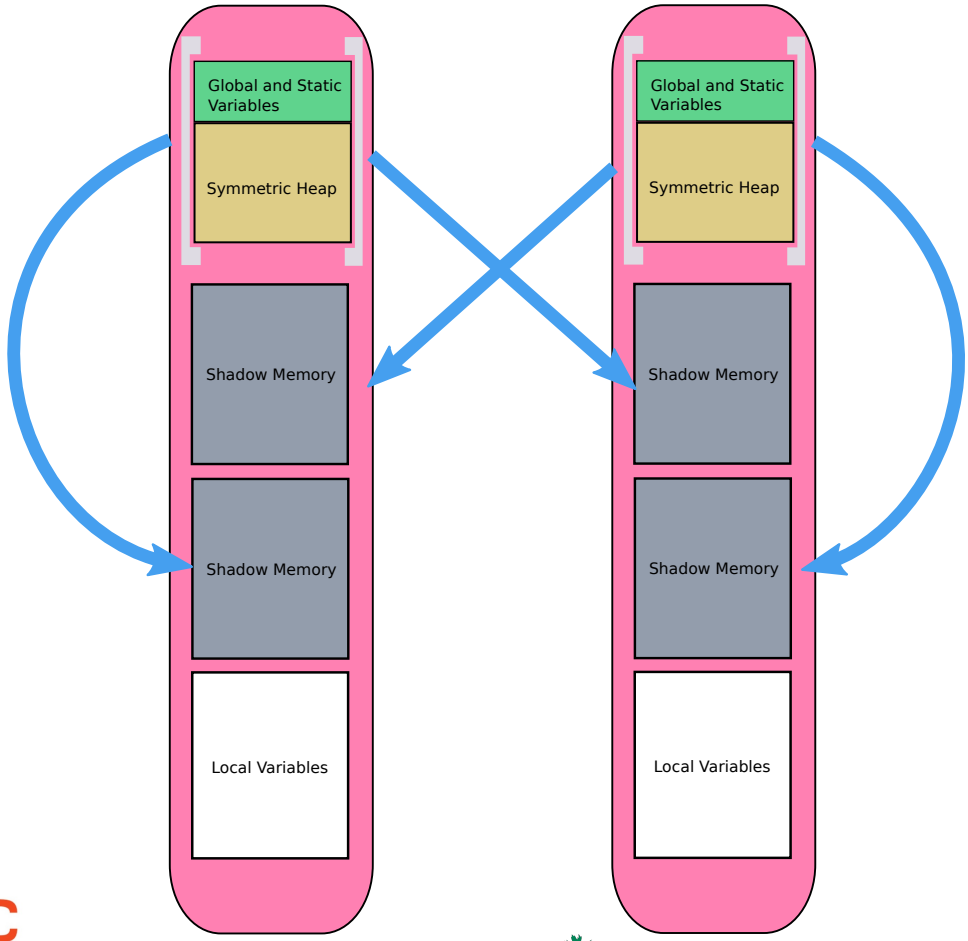
Restore selection

- PE fails – Checkpoint of partner lose
- Single backup VS. Dual backup

Dual backup


Global and Static Variables
Symmetric Heap
Shadow Memory
Shadow Memory
Local Variables

Dual backup


Global and Static Variables
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Local Variables
Global and Static Variables
Symmetric Heap
Shadow Memory
Shadow Memory
Local Variables

Single Backup VS. Dual backup

- Dual backup
  - Local restore benefit
  - Fully consistency
- Single backup
  - Better memory usage
  - Fit for some algorithms

API

- int shmem_checkpoint_all(void);
  Fault detection by return value. Return false indicates faliure happens. Always return false for substitute PE
- int shmem_query_fault(int **pes, int **pes_status, size_t *numpes);
  Check failed PE list.
- int shmem_restart_pes(int *pes, size_t num_pes);
  Collective reconstuction of PE to process mapping.
- int shmem_ft_algo_init(void);
  Guard the initialization code to avoid initialization stages on substitute PEs.

User Level Fault Mitigation

```
#include <shmem.h>
/* User algorithm states as global variables */
int step;
int main(int argc, const char *argv[])
{
    start_pes(0);
    if(shmem_ft_algo_init()){
        /* User algorithm initialization goes here */
    }
    do{
        if(SHMEM_FT_SUCCESS!=shmem_checkpoint_all()){
            int *pes, *pes_status;
            size_t numpes;
            shmem_query_fault(&pes,&pes_status,&numpes);
            shmem_restart_pes(pes,&numpes);
            shmem_barrier_all();
            free(pes);
            free(pes_status);
        }
        else{
            /* User algorithm computing loop goes here*/
            step++;
        }
    }while(step<MAX_STEP);
    /*User algorithm result report goes here*/
    return 0;
}
```

Implementation

- Based on UCCS
- Currently targetting spec 1.0
- Role changing
  Substitute PE change role from sub to work. Within shmem_restart_pes
- Process to PE remapping
  Substitute PE will take failed PE's PE number, no need to care about PE number change.
- Modules' reset, like shmem_barrier_all() Library/Algorithm initialization.

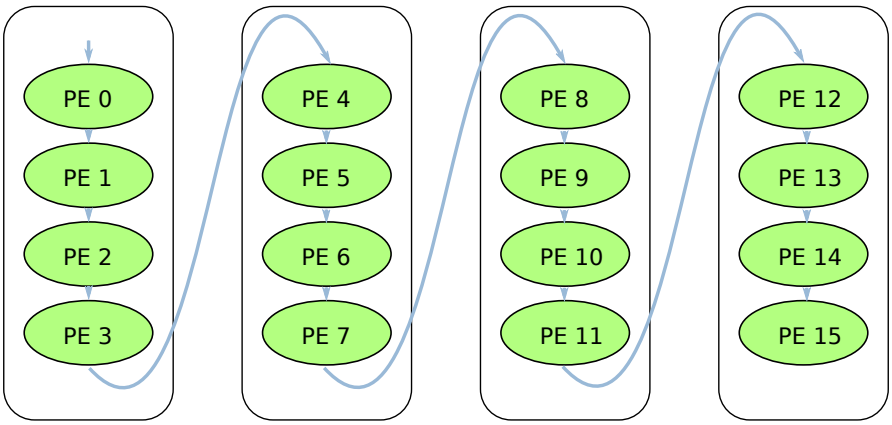
Implementation

Limitations:

- Currently using simple topology
  Current Ring. API do not limit the topology.
  More future work on topology adaption.
- Cannot shmalloc() within computing steps
  Metadata transferable allocator
- Only support dynamic linkage now
  In static, all symbols mingled. Need compiler to solve this.

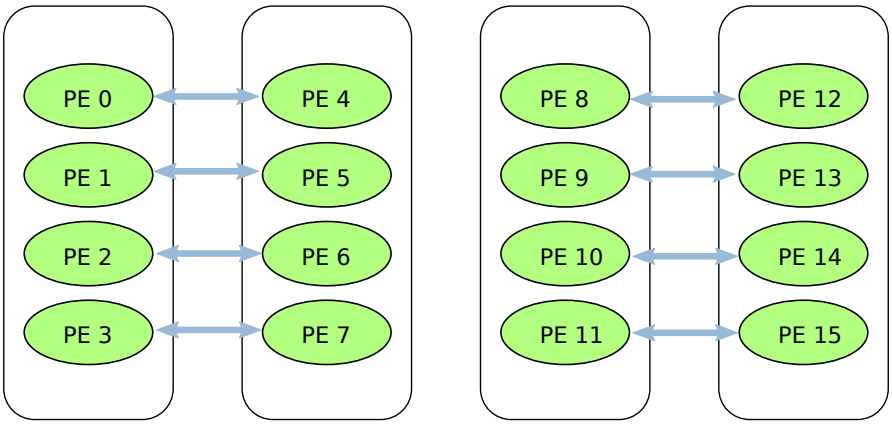
Some more talk about topology

Current implementation, for simplicity



Some more talk about topology

A better topology



Some more talk about topology

What is a good topology for backing up?

- Bandwidth usage
- Fault recovery ability
- Awareness
- Adaption

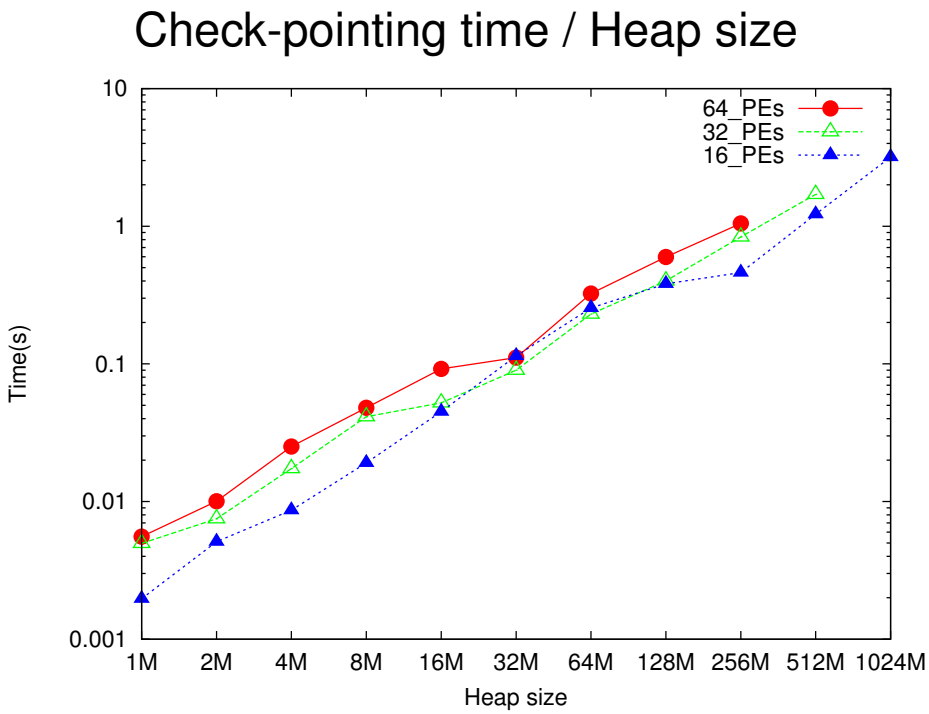
Evaluation

Crill cluster:

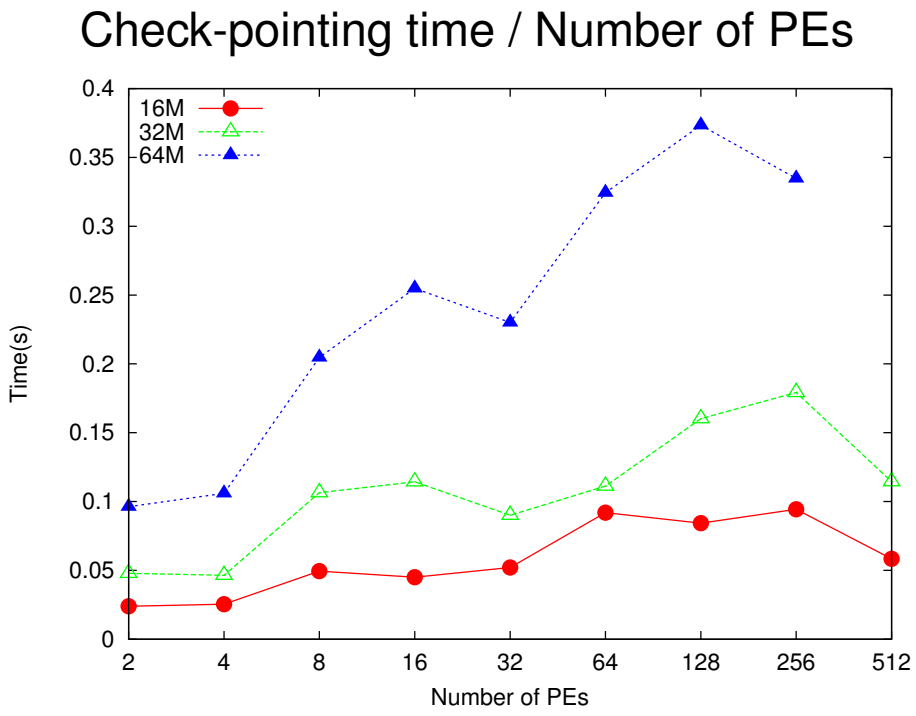
- 16 Nodes
- 2.2GHz AMD Opteron 6174 processor
- 64GB RAM on each node
- dual port Infiniband ConnectX HCA (20GB per second)

Process mapping: -bycore

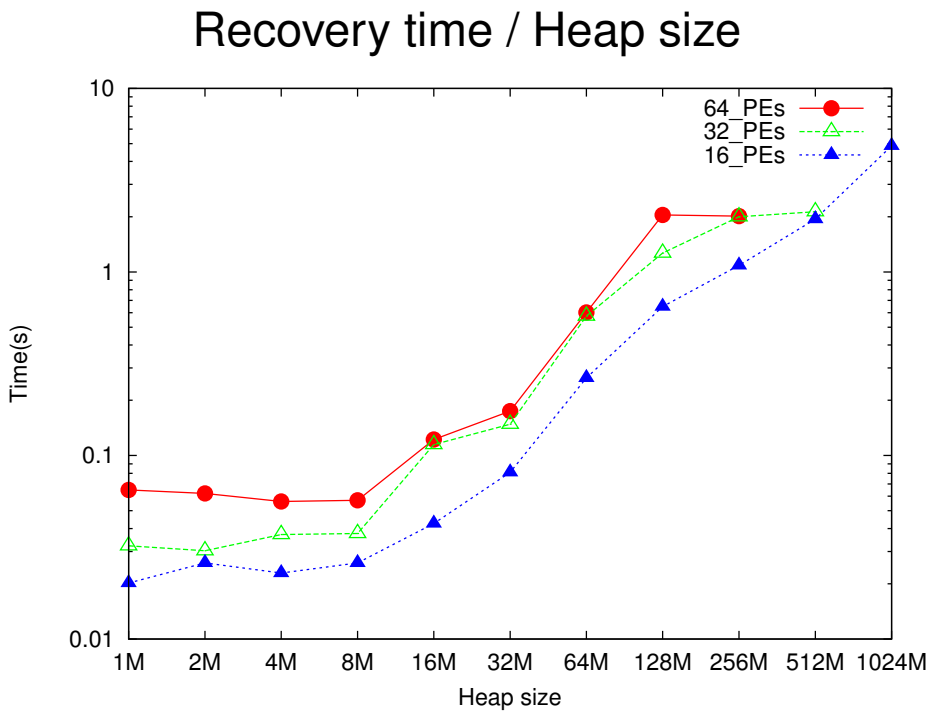
Evaluation


Check-pointing time / Heap size
64_PEs
32_PEs
16_PEs
Time(s)
10
1
0.1
0.01
0.001
1M
2M
4M
8M
16M
32M
64M
128M
256M
512M
1024M
Heap size

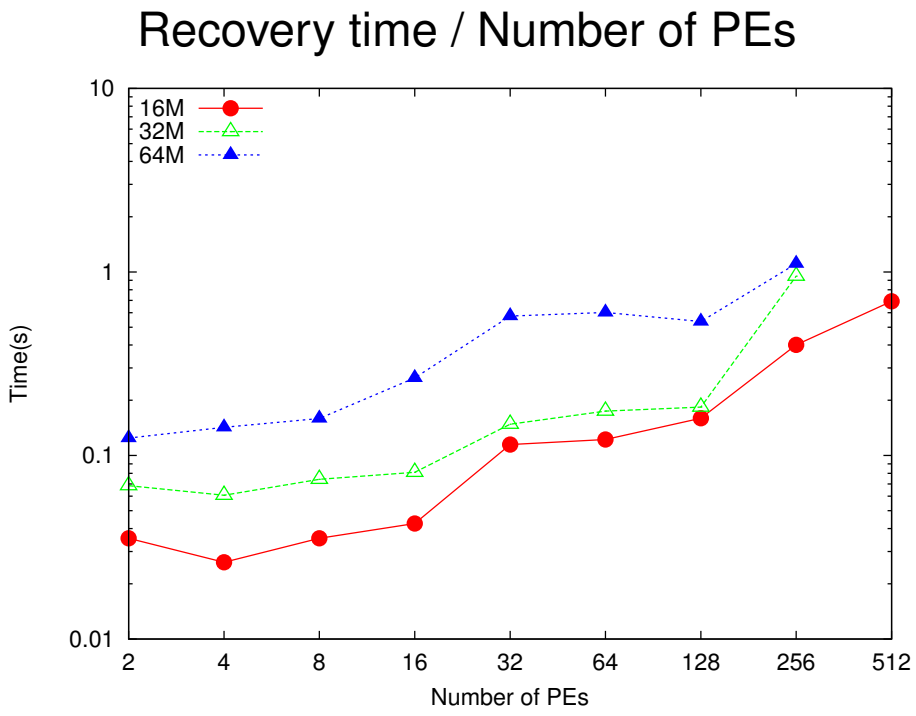
Evaluation


Check-pointing time / Number of PEs
16M
32M
64M
Time(s)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2
4
8
16
32
64
128
256
512
Number of PEs

Evaluation


Recovery time / Heap size
Time(s)
10
1
0.1
0.01
1M
2M
4M
8M
16M
32M
64M
128M
256M
512M
1024M
Heap size
64_PEs
32_PEs
16_PEs

Evaluation


Recovery time / Number of PEs
16M
32M
64M
Time(s)
10
1
0.1
0.01
2
4
8
16
32
64
128
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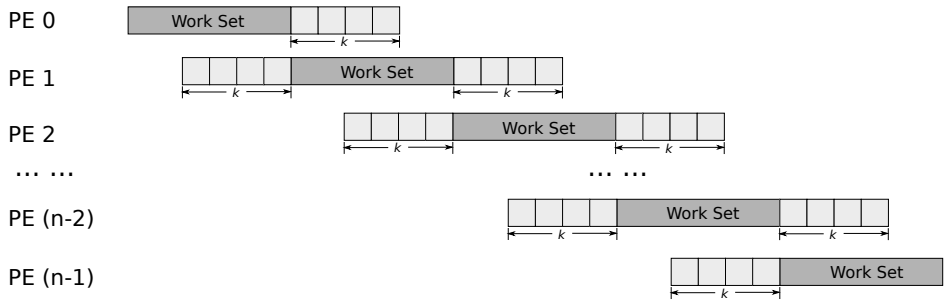
512
Number of PEs

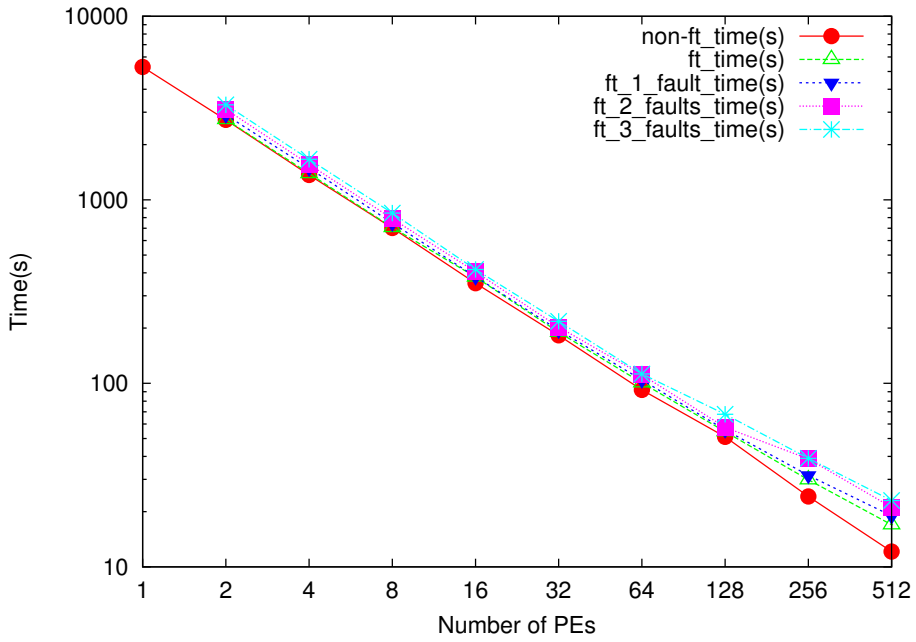
Evaluation

Jacobi 1D Stencil



Evaluation

Jacobi 1D, 64M size, 4096 iterations, 16 check-points



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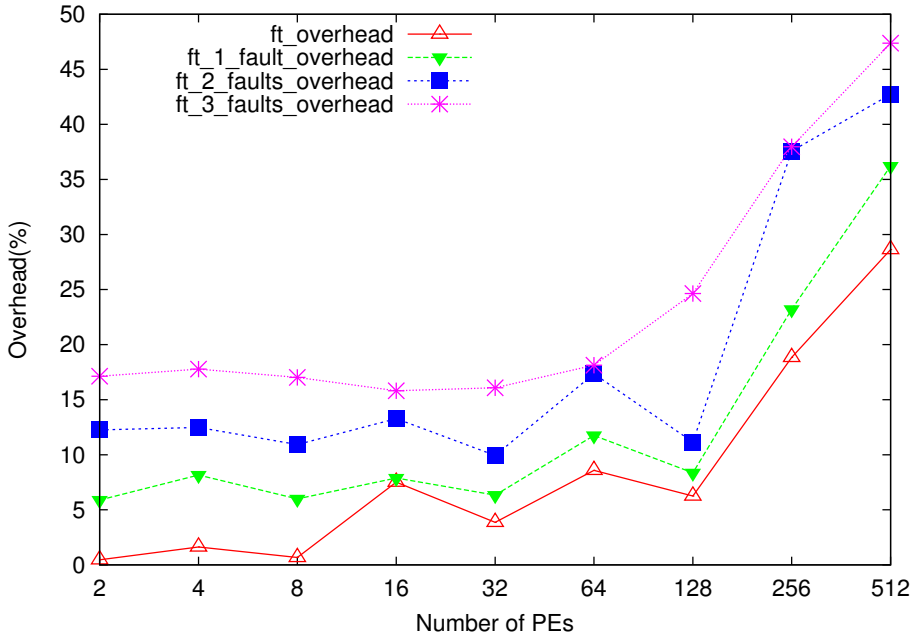

Summary

- Fault Tolerance ULFM for OpenSHMEM
- APIs
- Backup/Restore Strategy
- Evaluation

Future Work

- New comms layer, UCX
- New spec, catch up 1.2
- Topology Awareness and Adaption
- Combine with resonable fault detector

Acknowledgements

This work was supported by the United States Department of Defense & used resources of the Extreme Scale Systems Center at Oak Ridge National Laboratory.

Thank you!

Questions?

HPC TOOLS

OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY