

# Fault Tolerance for PCJ

Michał Szynkiewicz

Faculty of Mathematics and Computer Science Nicolaus Copernicus University,  
Toruń, Poland

**Abstract.** Nowadays, distributed computations are often run on large amounts of nodes for a significant amount of time. Having a 24 hour long computation on 1000 nodes means almost 3 years of computations. As calculated in [1], with 6 month mean time between failures, it gives less than 1% chance of success.

PCJ library is a high-performance parallel computing library for Java implementing PGAS model.

This paper describes changes introduced in PCJ to provide basic fault tolerance and fault tolerance strategies that are planned to be implemented in future.

## 1 Introduction

Before the changes described in this paper, any network or hardware failure resulted in hanging of a PCJ-based program.

The changes introduce *Ignore failure* fault tolerance policy. This is a minimum-overhead, no-checkpoint strategy.

For programs that do not require results from all nodes to finish, like Monte Carlo randomized algorithms, the strategy is enough to finish calculations properly. For other programs, the strategy provides a useful base on which the programmer may build a dedicated solution (e.g. replaying failed nodes work on other node).

## 2 PCJ library

PCJ library is a Java implementation of PGAS model. It is fast, lightweight and it ships as a single jar.

The smallest unit of computation in PCJ is called a *thread*. Each *thread* has its own local address space and shared address space. The owner thread accesses local and global address spaces variables as usual Java fields. Following is a description of PCJ features. For more details please see [3].

### 2.1 Synchronization

Threads synchronization in PCJ is realized by **barrier**. Barrier can be made either across all threads or two threads. In first case each task has to call **barrier** method.

## 2.2 Shared memory

Fields that should be put into shared address space have to be annotated in `@Shared` annotation. Aformentioned fields are accessible from other threads via following methods:

- `get(threadId, variableName), getFutureObject(threadId, variableName)`  
- read the value of given variable in a synchronous and asynchronous fashion
- `put(threadId, variableName, value)` - asynchronously update variable value on given node.
- `broadcast(variableName, value)` - asynchronously update variable value on all nodes.

`waitFor(variableName)` and `monitor(variableName)` can be used to lock the current thread until other thread updates given variable on this node.

## 3 Related work

As argued in [4], failures are becoming a norm in todays supercomputing systems. Hence, recently more and more parallel computing libraries start to provide fault tolerance features.

Authors of [4] propose a checkpoint/restart fault tolerance policy for OpenSHMEM - PGAS library with C and FORTRAN APIs. In the suggested model `shmem_checkpoint_all()` method is introduced. Call to `shmem_checkpoint_all()` will result in copying all of its shared (symmetric) data to another node. The method needs to be called on all nodes. Then, in case of a failure, the failed nodes can be restarted and job of all nodes can be started from the latest checkpoint. The power of this solution comes with the cost of synchronization of all nodes on every checkpoint.

[1] describes a fault tolerance policy for X10 language, asynchronous PGAS (APGAS) implementation. Language after changes is called Resilient X10. Resilient X10 introduces resilient storage that allows access to nodes data even if the node has failed and enables programmer to handle failures by throwing `DeadPlaceException` when node fails.

## 4 Fault tolerance

TODO: Always alive node0 - why is it ok - gathering results + arguments from [4] TODO: outline of algorithm

### 4.1 API

The main concern for the API changes provided by the implementation is not to break

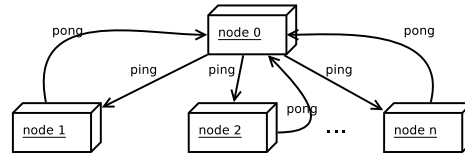
### Impact on API

## 4.2 Node failure handling implementation

The main elements of implementation are: monitoring nodes for failure and adjusting configuration after node failure.

**Node monitoring** Monitoring works in two ways::

- The immortal *node 0* is monitoring other nodes by sending PING message and waiting for PONG. If, for some node, sending PING fails, or the node does not answer with PONG for a long (configurable) time, it is assumed failed. Please see Fig. 1 Node monitoring.
- If *node A* encounters a communication error when trying to communicate with *node B* (e.g. if updating a variable value on *node B* fails), *node A* informs *node 0* that *node B* has failed.



**Fig. 1.** Node monitoring

**Reconfiguration** On node failure *node 0* sends a proper reconfiguration message to all nodes. Depending on the type of selected strategy there are two...

## 4.3 Performance overhead

## 5 Future work

### 5.1 Resilient storage implementation

## 6 Conclusion

## References

1. Leslie Lamport, Dave Cunningham, Dave Grove, Ben Herta, Arun Iyengar, Kiyokuni Kawachiya, Hiroki Murata, Vijay Saraswat, Mikio Takeuchi, Olivier Tardieu *Resilient X10. Efficient failure-aware programming*, Proceedings of the 19th ACM SIGPLAN symposium on Principles and practice of parallel programming
2. Marek Nowicki, Piotr Bała *PCJ - New Approach for Parallel Computations in Java* Applied Parallel and Scientific Computing, 11th International Conference, PARA 2012, Helsinki, Finland, June 10-13, 2012, Revised Selected Papers

3. Marek Nowicki, Piotr Bała *PCJ. Parallel Computing in Java*, 2013, [Online]. Available: [http://pcj.icm.edu.pl/c/document\\_library/get\\_file?uuid=e8b5a416-644d-43d0-a19c-74e14555ef96&groupId=43801](http://pcj.icm.edu.pl/c/document_library/get_file?uuid=e8b5a416-644d-43d0-a19c-74e14555ef96&groupId=43801) [2015, April 14]
4. Pengfei Hao, Pavel Shamis, Manjunath Gorentla Venkata, Swaroop Pophale, Aaron Welch, Stephen Poole, Barbara Chapman, *Fault Tolerance for OpenSHMEM*, PGAS/OUG14 Available: [http://nic.uoregon.edu/pgas14/oug\\_submissions/oug2014\\_submission\\_12.pdf](http://nic.uoregon.edu/pgas14/oug_submissions/oug2014_submission_12.pdf) [2015, April 17.]