NEWT - A fault tolerant BSP framework on Hadoop YARN

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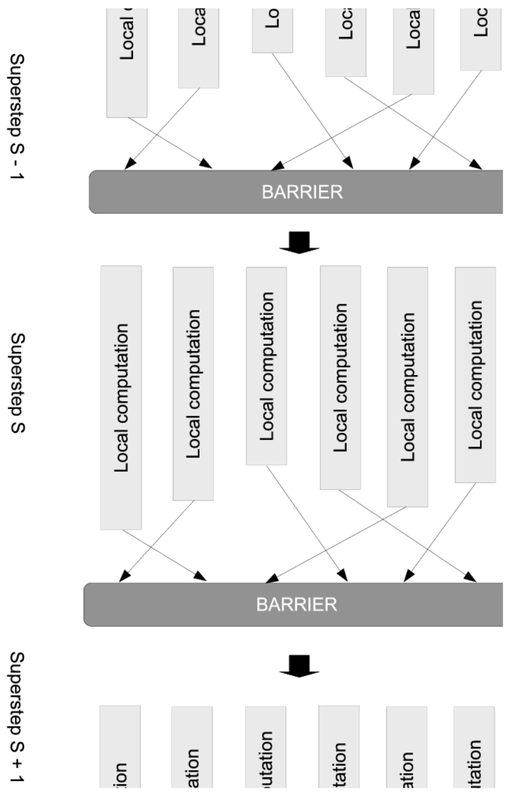
Introduction

We looked for a distributed computing framework that could be utilized for running iterative scientific computing algorithms in the cloud, but most solutions proved lacking in some respect. This is why we decided to create our own with the following goals:

- Provide automatic fault recovery.
- Retain the program state after fault recovery.
- Provide a convenient programming interface.
- Support (iterative) scientific computing applications.

The bulk synchronous parallel model faciliates many of these goals, hence we based our approach on it.

Bulk Synchronous Parallel



A BSP [1] based program consists of a series of supersteps, each divided into three stages:

- **Concurrent computation**
- **Communication**
- **Barrier synchronization**

One of the main advantages of this scheme is elimination of race conditions (related to message passing) and deadlocks, by avoiding circular data dependencies.
Another advantage is that the BSP program structure can be naturally exploited for fault tolerance.
Previous experience with existing BSP-based frameworks showed that most current solutions do not satisfy our requirements for scientific computing applications [6].

NEWT

Models such as MapReduce [5] and Pregel [2] have previously used BSP to craft transparently fault tolerant distributed computing frameworks. However, in these cases fault tolerance relied on restricted programming models. We propose a more open ended approach, which uses a concept similar to continuation passing.
The program under NEWT is a mapping of functions and their labels, with each function having a explicitly defined continuation – the next function in the sequence. Additionally a state object is defined, which is passed from function to function. The rest is handled by the framework.

The following simple loop is at the core of the framework.

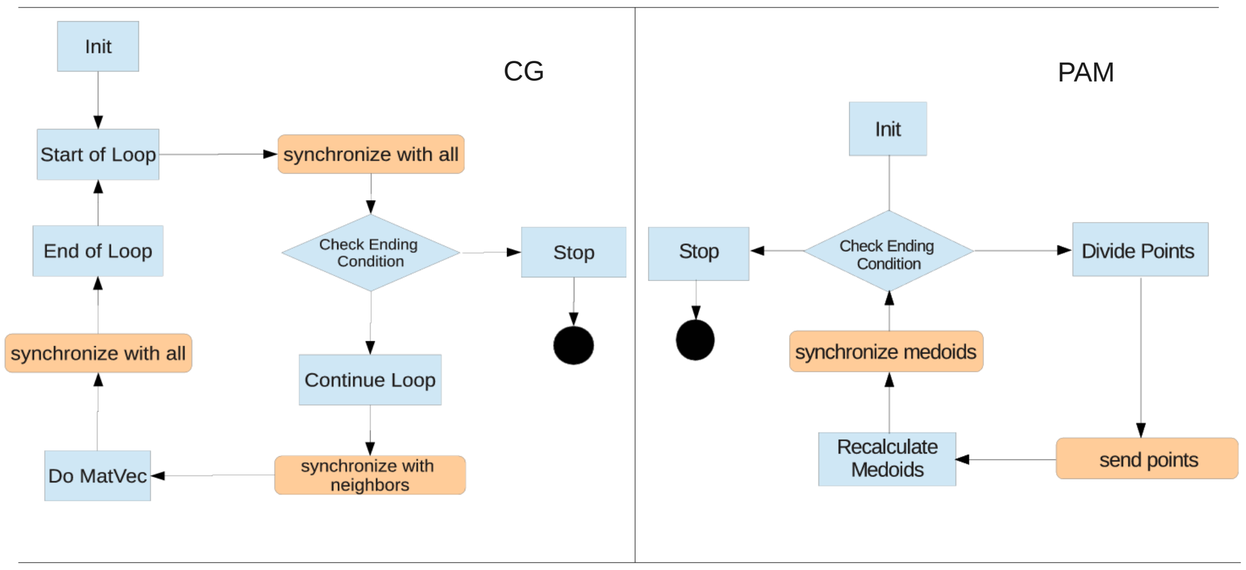
```
state = initialState
next = initialLabel
while(true)
    next = execute(next, state, comm)
    barrier(comm)
    < insert fault tolerance here> :)
    if (next == none)
        break
end while
```

Transparent fault tolerance is achieved by checkpointing the state object into persistent storage, similarly to what Pregel does with it's vertex values. The same structure allows for features such as process migration to be added.

Adapting Algorithms

The proposed approach requires one to view an algorithm as a finite state machine, where the separation between states is governed by the need of synchronizing some state variables.

The following figures show the application of this approach to two well known iterative algorithms, conjugate gradient method (CG) and partitioning around medoids clustering (PAM).



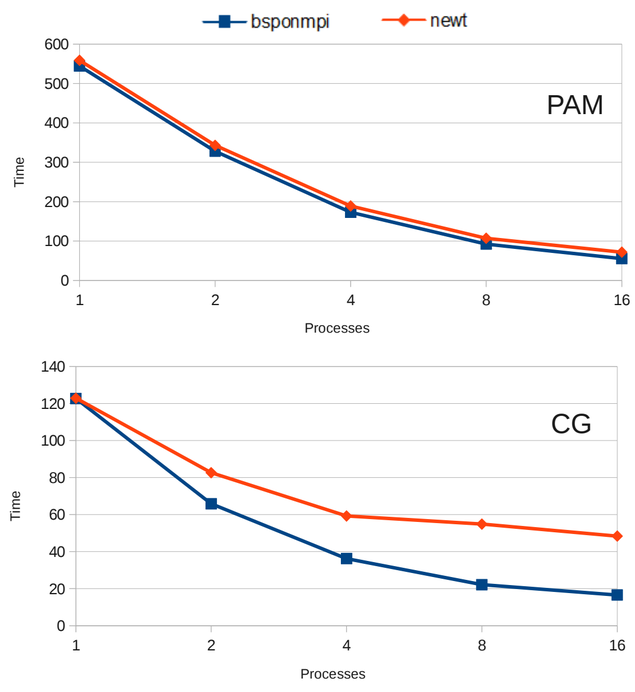
Running on Hadoop YARN

Fault-tolerance requires a scheduling mechanism and a resilient storage environment.
These can be provided by the Apache Hadoop project, since with the introduction of YARN, Hadoop cluster resources can be utilized by frameworks other than MapReduce. As such the following components were used in implementing NEWT:

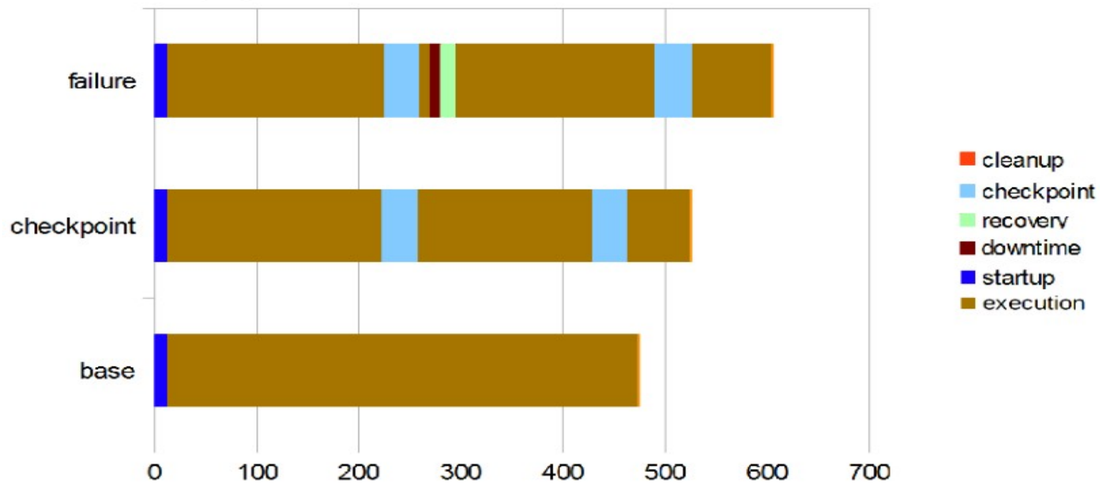
- Apache Hadoop YARN (Yet Another Resource Negotiator) - provides resource management, process scheduling and monitoring. [3]
- Apache HDFS (Hadoop Distributed File System) - provides a highly fault-tolerant distributed file system, that was designed to be run on commodity hardware.
- Apache MINA – provides message passing through socket connections. [4]

Evaluation

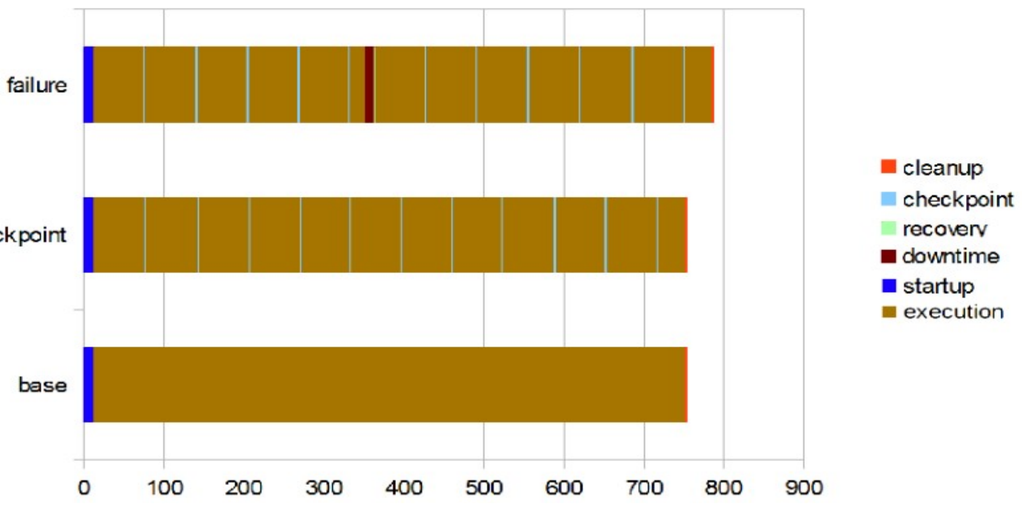
We've run scaling experiments on the prototype, showing it scales as well as MPI for coarse grained iterative algorithms (PAM), but, comparing to MPI, has a bit too much synchronization overhead for fine grained ones (CG), which leaves room for more optimization (such as an unbuffered communication mode).
Additionally we measured the overhead of the framework's fault tolerance mechamisms.



A. *Conjugate Gradient method*



B. *Partitioning Around Medoids clustering*



References

[1] L. G. Valiant, “A bridging model for parallel computation,” Commun. ACM, vol. 33, no. 8, pp. 103–111, Aug. 1990.
[2] G. Malewicz, M. H. Austern, A. J. Bik, J. C. Dehnert, I. Horn, N. Leiser, and G. Czajkowski, “Pregel: a system for large-scale graph processing,” in Proceedings of the 2010 ACM SIGMOD.
[3] Apache Software Foundation. (2013, Jun.) Apache hadoop yarn Available: http://hadoop.apache.org/docs/current/hadoop-yarn/hadoop-yarn-site/YARN.html
[4] ——. (2013, Jun.) Apache mina. Available: http://mina.apache.org/
[5] S. N. Srirama, P. Jakovits, E. Vainikko: Adapting Scientific Computing Problems to Clouds using MapReduce, FGCS Journal, 28(1):184-192, 2012.
[6] P. Jakovits, S. N. Srirama, I. Kromonov: Viability of the Bulk Synchronous Parallel Model for Science on Cloud, HPCS 2013, pp. 41-48. IEEE.

NEWT webpage: **http://mc.cs.ut.ee/mcsite/projects/newt**