VolpexMPI: robust execution of MPI applications through process replication

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Contributors

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Outline

- Introduction and Motivation
- VOLPEX project overview
- VolpexMPI
  - design and concept
  - performance results on a homogeneous cluster
  - target selection problem
  - performance results on a ‘heterogeneous’ cluster
- Overview of ongoing work

Volpex: Parallel Execution on Volatile Nodes

- Fault tolerance: why?
  - Node failures on machines with thousands of processors
  - Node and communication failure in distributed environments
  - Very long running applications
  - Security relevant applications
- Volpex Project Goals:
  - Execution of communicating parallel programs on volatile ordinary desktops
  - Key problem: High failure rates AND coordinated execution
Major Challenges in VOLPEX

- Failure Management
  - Replicated processes
  - Independent process checkpoint/recovery
- Programming/Communication Model
  - Volpex Dataspase API
  - VolpexMPI
- Execution management
  - Selection of “good” nodes for execution
  - Integration with BOINC/Condor
  - Simulation to identify suitable codes (Dimemas)

Volpex Goals:
- Application progress tied to the fastest process replica(s)
- Seamless progress despite failures
- Minimum overhead of redundancy

The Volpex Approach

Redundancy and/or independent checkpoint/restarts
→ multiple physical processes per logical process

Volpex Goals:
- Application progress tied to the fastest process replica(s)
- Seamless progress despite failures
- Minimum overhead of redundancy
**Dataspace Programming Model**

- Independent processes communicate with one way, PUT/GETs with an abstract dataspace
  - Similar to Linda, Javaspaces, Tspaces etc.

  \[
  \begin{align*}
  \text{PUT (tag, data)} & \quad \text{place data in dataspace indexed with tag} \\
  \text{READ (tag, data)} & \quad \text{return data matching the tag} \\
  \text{GET (tag, data)} & \quad \text{return and remove data matching tag}
  \end{align*}
  \]

- Fault tolerance approach (checkpoint or replication) implies redundant processes execution
  - a logical PUT/GET may be executed many times
  - a late replica may PUT a value that is out of date

**VolpexMPI**

- MPI library for execution of parallel application on volatile nodes
- Key features:
  - controlled redundancy: each MPI process can have multiple replicas
  - Receiver based direct communication between processes
  - Distributed sender logging
- Prototype implementation supports ~40 MPI functions
  - point-to-point operations (blocking and non-blocking)
  - collective operations
  - communicator management
Point-to-point communication

- Goal: efficient handling of multiple replicas for each MPI process
  - avoid sending each message to all replicas
- Concept:
  - receiver based communication model
    - sender buffers message locally
    - receiver contacts sender process requesting message
    - sequence numbers used for message matching in addition to the usual message envelope (tag, communicator, sender rank, recv rank)
  - no support for MPI_ANY_SOURCE as of today

Volpex MPI design

- Data transfer based on non-blocking sockets
  - supports timeout of messages and connection establishment
  - handling of failed processes
  - adding of new processes at runtime
- Sender buffer management:
  - circular buffer containing message envelopes and data
  - oldest log-entries are being overwritten
  - size of the circular buffer limits as of today ability to retrieve previous messages
Managing Replicated MPI processes

- Team based approach:
  - Processes are spawned in teams
  - Only in case of failure, processes from different team is contacted
  - Optimal for homogeneous environments

Bandwidth comparison

- 4 byte latency over Gigabit Ethernet:
  - Open MPI v1.4.1: ~50us
  - VolpexMPI: ~1.8ms

![Bandwidth comparison graph](image)
NAS Parallel Benchmarks

- Normalized execution times of VolpexMPI on a dedicated cluster over Gigabit Ethernet
- Open MPI v1.4.1 reference times are 100

Influence of redundancy level

- Performance impact of executing one (x1), two (x2) and (x3) replicas of each process
- Normalized to the single redundancy VolpexMPI execution times
Influence of process failures

- Double redundancy
- Failing processes from both teams
- Normalized to the double redundancy execution times

The Target Selection Problem revisited

- Identifying best set of replicas

- Beneficial to connect to fastest replica
- Will make fast replica slow by making it handle more number of requests
Target Selection Algorithms

- **RO**: Response Order Algorithm
  - Request a message from all replicas of a given MPI rank
  - Target is selected based on response order of replicas
  - Regularly repeated during execution

- **ERO**: Extended Response Order Algorithm
  - Same preliminary steps as RO
  - Change to next (slower) target in the list if difference in newest sequence number for a particular message exceeds a given threshold

Target Selection Algorithms (II)

- Double redundancy tests on a heterogeneous configuration
  - fast nodes: Gigabit Ethernet, 2.2 GHz
  - slow nodes: Fast Ethernet, 1.0 GHz
  - Initially, both teams contain processes on fast and slow nodes
  - Each MPI rank has one fast and one slow process
  - Normalized towards double redundancy numbers on GE

![Chart showing execution time for 8 and 16 processes]
Beyond volunteer systems

- Experiments over InfiniBand in the planning
  - using RDMA Get operation would improve performance
  - requires changes in the message logging
- Beyond the MPI API
  - Functions to compare values of a variable across replicas
  - API allowing to perform operations on a single copy of a replica
    - e.g. result file written by a single replica of a process
  - API allowing to split execution of an operation across all replicas

Summary

- Volpex MPI allows for the seamless handling of multiple process replicas of MPI process
  - minimal or no performance penalty due to replication
  - seamless handling of process failures
  - different target selection algorithms for homogeneous and heterogeneous environments
- Application have to carefully chosen for volunteer computing
  - communication/computation ratio
  - low degree of communication
Edgar Gabriel

Very good....until it melts....
Reviewer: des kita power on Dec 06, 2009
Customer Rating: 1.8

I bought this CPU as an upgrade for my video editing suite and after a week of use, my computer just shut off and I started smelling burnt silicone. I inspected my computer and found that half the socket was melted. I do NOT recommend this CPU because of its obviously poor design. I already wrote a letter to Intel about this. Guess I should have used a CPU fan?

FAIL