A Cluster-Based Implementation of a Fault Tolerant Parallel Reduction Algorithm Using Swarm-Array Computing

Authors:
Blesson Varghese, ***Gerard McKee,*** *Vassil Alexandrov*
School of Systems Engineering
University of Reading, United Kingdom
E-mail: b.varghese@student.reading.ac.uk,
g.t.mckee@reading.ac.uk, v.n.alexandrov@reading.ac.uk

Table of Contents

- Introduction
- Swarm-Array Computing
- Proof of Concept
- Implementation
- Impact
- Conclusion

Introduction - 1

- Fault Tolerance
  - Important issue in distributed parallel computing systems
  - High level view
    - Reliable business systems – continue operation when system components have failed
  - Low level view
    - Reduce impact of failure when it occurs – seamlessly continue execution of a task

Introduction - 2

- Two types of fault tolerance:
  - Reactive Fault Tolerance
    - Reduce impact of failure when it occurs
    - “Response after failure occurs”
  - Proactive Fault Tolerance
    - Predicts failures likely to occur
    - “Responding when a failure is likely to occur”

- Research in this paper focuses on *Proactive Fault Tolerance*

Introduction - 3

- Modern day fault tolerance
  - Technology used – Multi-agent Systems
  - Classification of Multi-agent fault tolerance:
    - Fault tolerance of multi-agent framework
    - Fault tolerance of individual agent in the framework

- Existing research on multi-agent based fault tolerance does not explore the extension and implementation of such ideas for large scale parallel computing systems

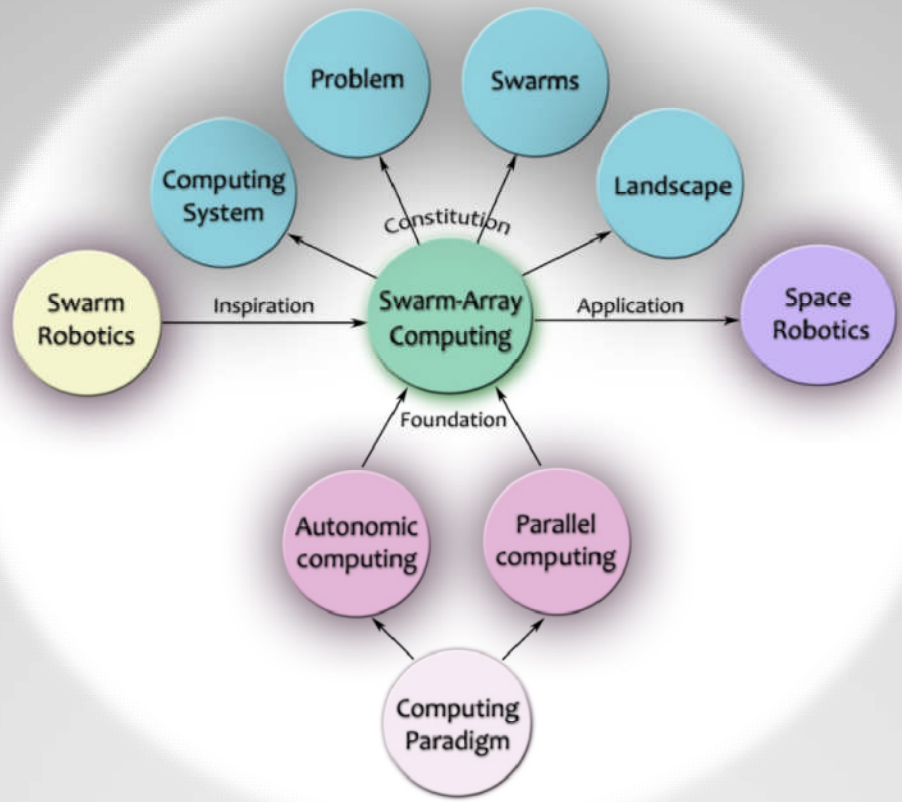
Introduction - 4

- Question that needs to be addressed:

"How can a bridge between fault-tolerance in multi-agent systems and parallel computing systems be built?"

Hence, Swarm-Array Computing is proposed.

Swarm-Array Computing - 1



Swarm-Array Computing - 2

- Constitution
  - Computing Systems
    - Field Processing Gate Arrays (FPGAs) and Computer Clusters used in this study
    - Cores can be considered as ‘intelligent cores’
  - Problem/Task
    - A Task to be executed can be considered as a swarm of autonomous agents
    - Tasks can be considered as ‘intelligent agents’

Swarm-Array Computing - 3

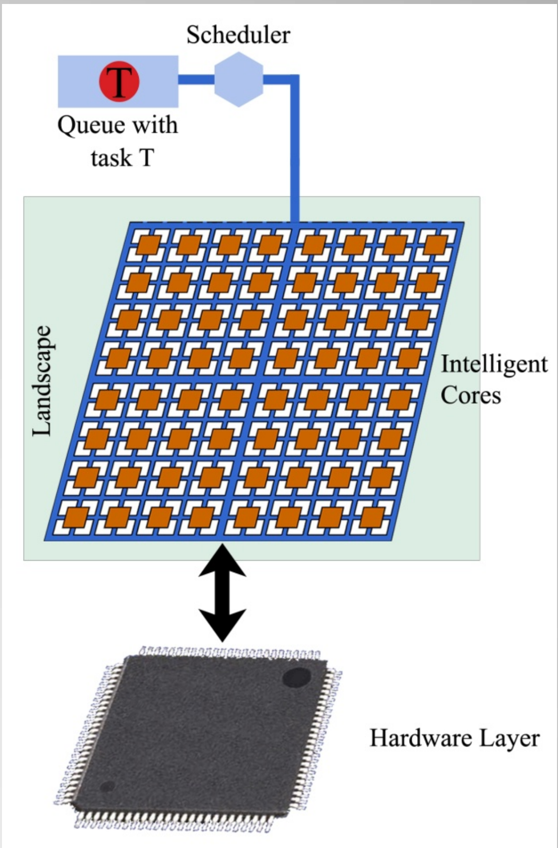
- Constitution (contd.)
  - Swarms
    - Combination of Intelligent Cores and Intelligent Agents
  - Landscape
    - Arena in which cores and agents interact with each other
    - Defines the state of the computing system and the task being executed

Swarm-Array Computing - 4

- Approaches
  - Fits the Swarm-Array computing constituents together
  - Three approaches
    - First Approach - Intelligent Cores
    - Second Approach - Intelligent Agents
    - Third Approach - combinative approach considering both Intelligent Cores and Intelligent Agents

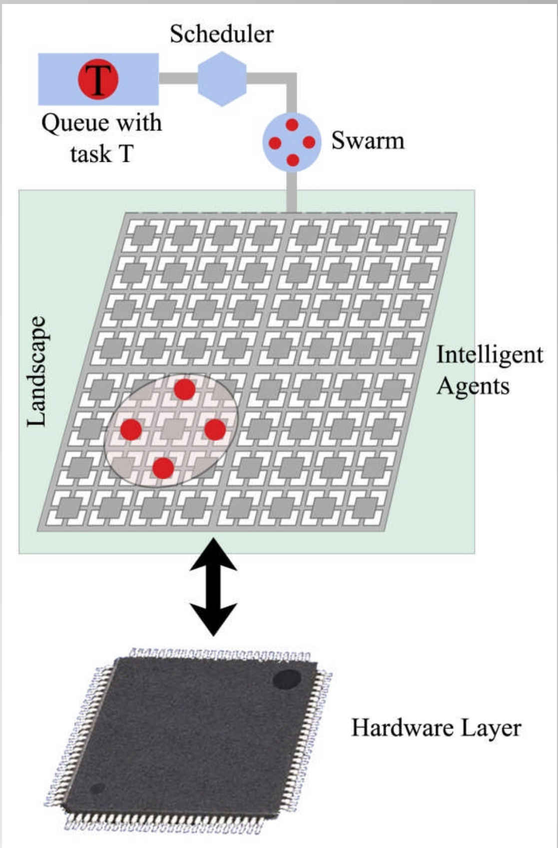
Swarm-Array Computing - 5

- Approaches (contd.)
  - First Approach - Intelligent Cores
    - Hardware abstracted to intelligent cores
    - On the event of a failure, tasks can get transferred from one core to another
    - Landscape – the arena on which the task gets executed



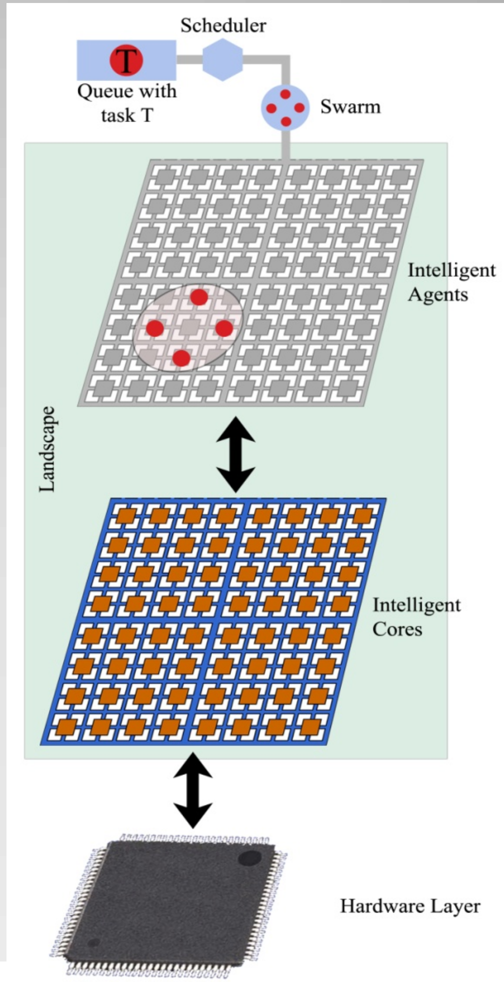
Swarm-Array Computing - 6

- Approaches (contd.)
  - Second Approach - Intelligent Agents
    - Hardware layer abstracted
    - Tasks mapped onto autonomous swarm agents
    - On the event of a node failure, agents move from one core to another
    - Landscape – the arena on which the agents traverse
- Intelligent Agent based approach considered in this paper



Swarm-Array Computing - 7

- Approaches (contd.)
  - Third Approach - Intelligent Cores and Intelligent Agents
    - Combination of the first and second approach



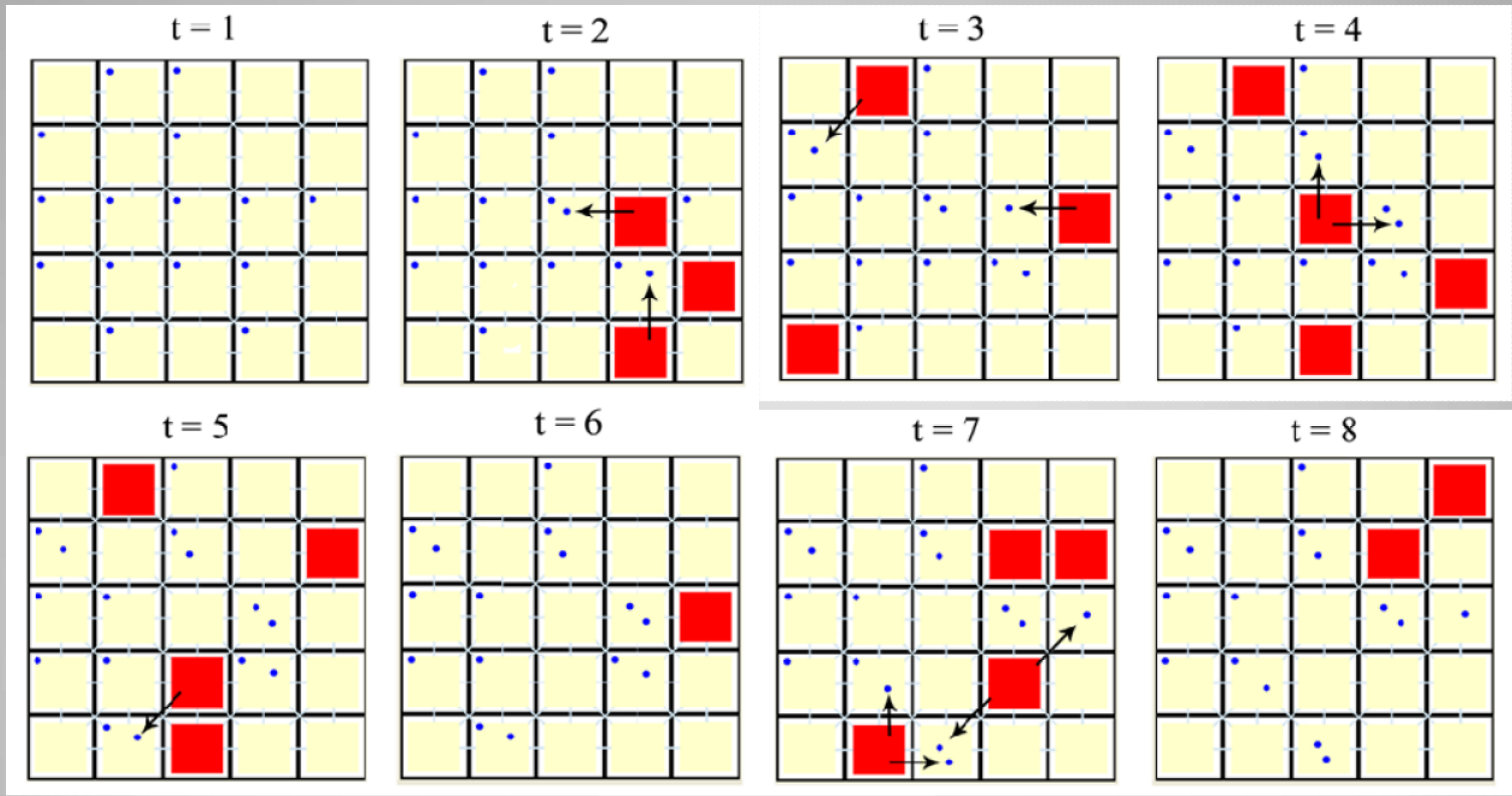
Proof of Concept - 1

- Experimental Environment
  - Multi-agent simulator the best option
  - SeSAm (Shell for Simulated Agent systems) simulator
    - Provision for modelling agents, world and simulation runs
- Modelling
  - The cores of the FPGA modelled as agents
  - 5 X 5 regular grid FPGAs considered

Proof of Concept - 2

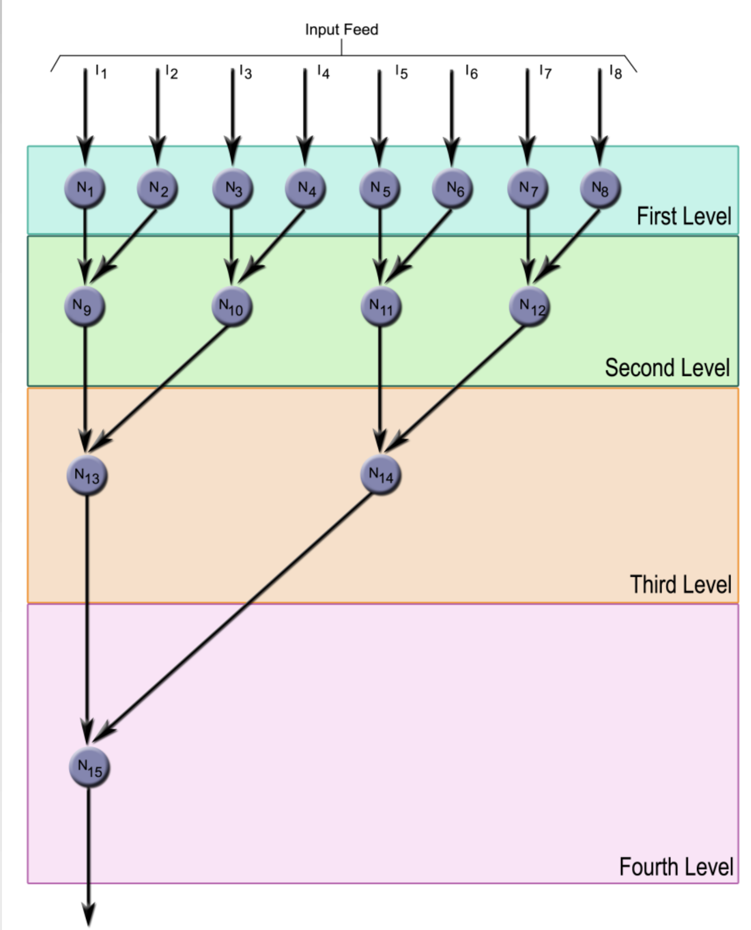
- Modelling (contd.)
  - Core temperature simulated
  - Approach 2 – Intelligent Agents
    - When core temperature increases beyond a threshold, the agent executing on a core moves to another core

Proof of Concept - 3



Implementation - 1

- What tasks can benefit from Swarm-Array Computing?
  - Parallel Reduction Algorithms
    - the computing nodes of a parallel reduction algorithm tend to be critical
    - employed in critical applications such as space applications



Implementation - 2

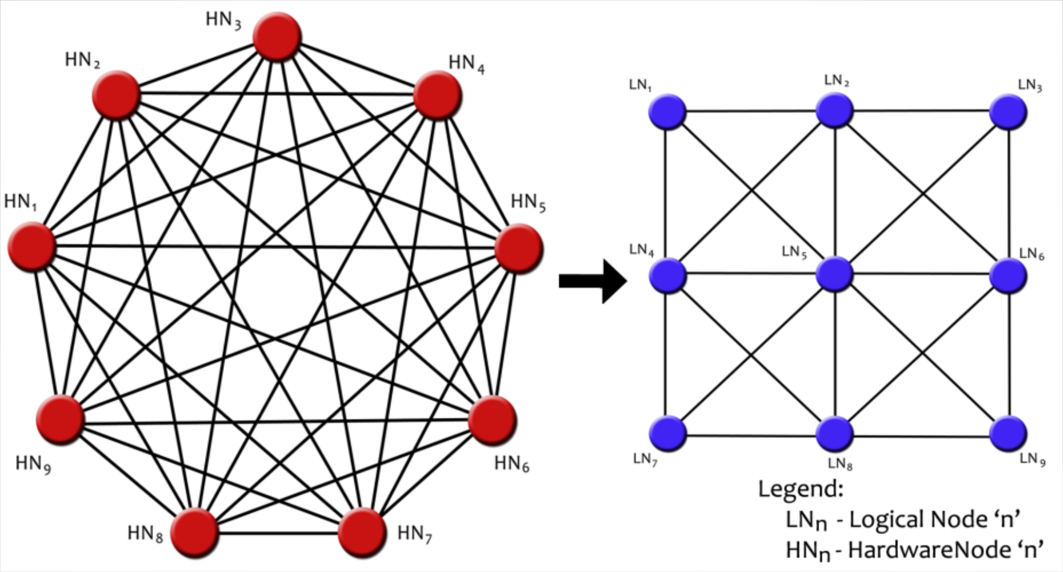
- Resources:
  - ACET Teaching Cluster used as computing platform
  - 1 head node and 33 compute nodes
  - Connected via the Gigabit Ethernet switch
  - All communications through TCP
- Middleware
  - Open MPI 1.3.3, open source implementation of MPI (Message Passing Interface) version 2.0
  - Supports Dynamic Process Creation and management

Implementation - 3

- Two Parallel Reduction Algorithm Implementations:
  - Classic Version
    - No fault tolerant concepts
    - If used in critical versions would stall the algorithm
  - Fault Tolerant Version
    - Implemented using 'Intelligent Agents' in Swarm-Array Computing

Implementation - 4

- Landscape:
  - Rules / Policies for abstraction
  - Hardware nodes abstracted to logical nodes



Implementation - 5

- Each process executing on a node gathers some sensory information
  - Prediction on whether a node is likely to fail
  - Similar to proactive fault tolerance.
- Node temperatures simulated
  - When the temperature of a node rises beyond a threshold, the process executing on that node predicts a failure
  - Spawn a new process on an adjacent core in the abstracted layer.
- The agent on the abstracted core expected to fail shifts to the adjacent core on which the new
- Dependency information carried by the agent that was shifted to the new core is employed to reinstate the state of execution of the algorithm.
- Ensures that information is not lost and does not affect the final solution in critical applications.

Impact

- Useful for space applications
  - Space crafts employ FPGAs
  - When space craft leaves the atmosphere, Single Event Upsets (SEUs) likely to occur due to radiations
  - Hardware reconfiguration or software uploading from earth extremely impossible
  - Hence self-managing approach required
  - Swarm-Array Computing can come to play

Conclusion

- `Intelligent Agent' approach in Swarm-Array Computing considered
- Proof of concept validated on a multi-agent simulator
- Implementation on the ACET teaching cluster using Open MPI
- Two implementations – classic vs fault tolerant
- Traditional Fault Tolerant methods can be replaced

Thank you for your undivided attention