Sequoia Code Development Challenges and Tools Infrastructure

CScADS Tools Workshop

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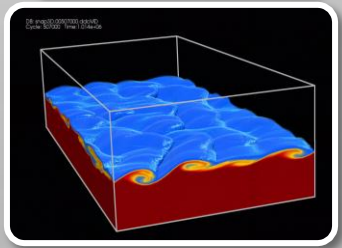
We are on track to deliver Sequoia in 2012.

- Sequoia statistics
  - 20 petaFLOP/s target
  - Memory 1.5 PB, 4 PB/s bandwidth
  - 1.5M cores
  - 3 PB/s link bandwidth
  - 60 TB/s bi-section bandwidth
  - 0.5−1.0 TB/s Lustre bandwidth
  - 50 PB disk
- 9.6MW power, 4,000 ft^2
- Third generation IBM BlueGene
- Challenges
  - Hardware scalability
  - Software scalability
  - Applications scalability

- Sequoia 20 petaFLOP/s
  - Deliveries completed on April 16
  - Unclassified science throughout 2012
  - Acceptance: September 2012
  - Classified: January 2013
  - Tri-lab production use follows



Acceptance Criteria:

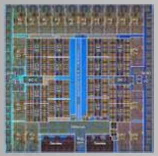
UQ: Run 24 simultaneous Purple-class Integrated Design Code calculations

while also running…

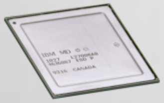
Weapons science: at 4 PF sustained

Sequoia builds on 96 racks of the IBM Blue Gene /Q architecture.

1. Chip
16 cores

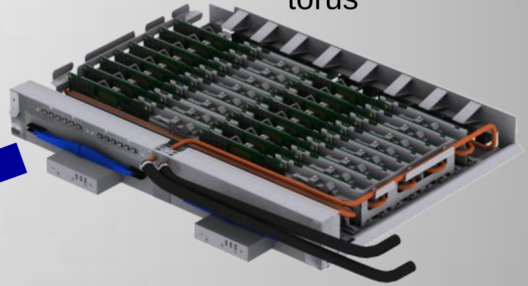


2. Module
Single chip



3. Compute card
One single chip module,
16 GB DDR3 memory

4. Node card
32 compute cards,
Optical modules, link chips,
torus

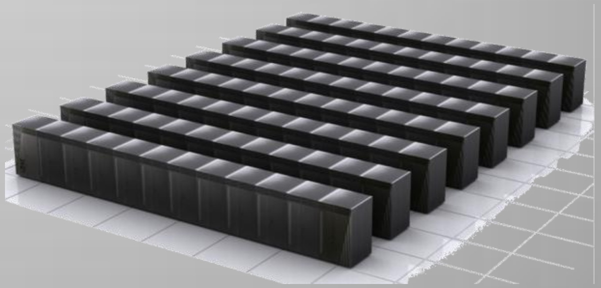


5b. I/O drawer
8 I/O cards
8 PCIe Gen2 slots

5a. Midplane
16 node cards

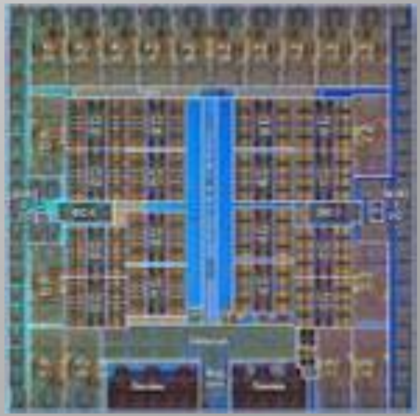
6. Rack
2 midplanes
1, 2, or 4 I/O drawers

7. System
20 PF/s

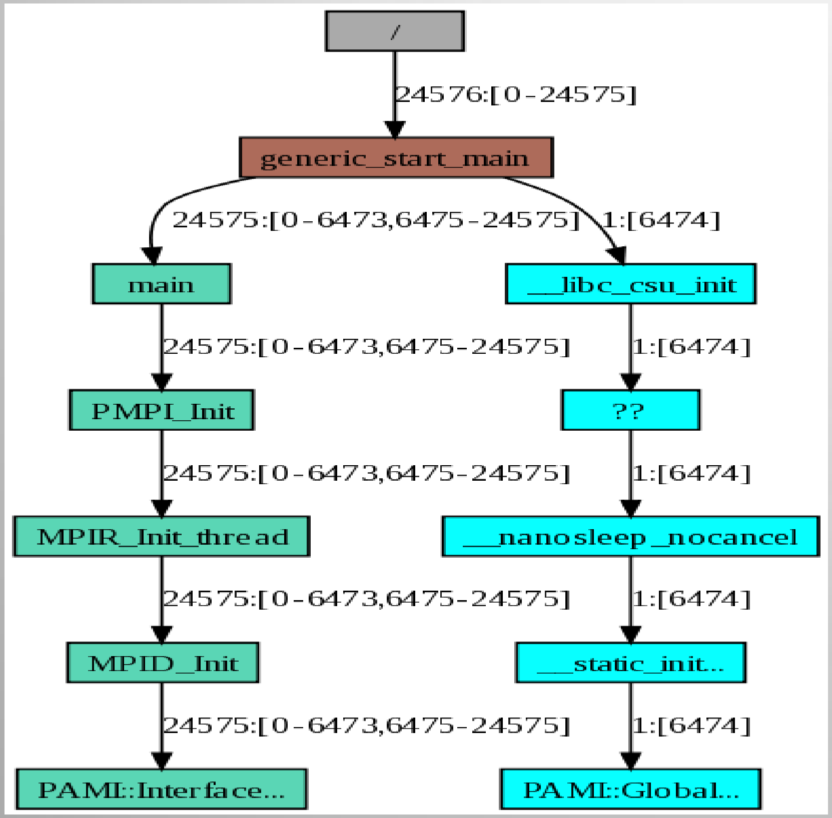


Threading is key to BG/Q's energy efficiency and performance.

- Mitigates single-issue, in-order processor constraints
  - Four HW threads/core maximizes function unit utilization
  - Latency hiding
  - More opportunities than out-of-order execution
- Supported by new hardware features
  - 16 L2 instructions supporting fast barriers, work queues, etc.
  - Transactional memory
  - Speculative execution
- Works well with other BG/Q technologies
  - 4-wide SIMD unit
  - Prefetching



Problems that arise at large-scale are the rule rather than the exception.



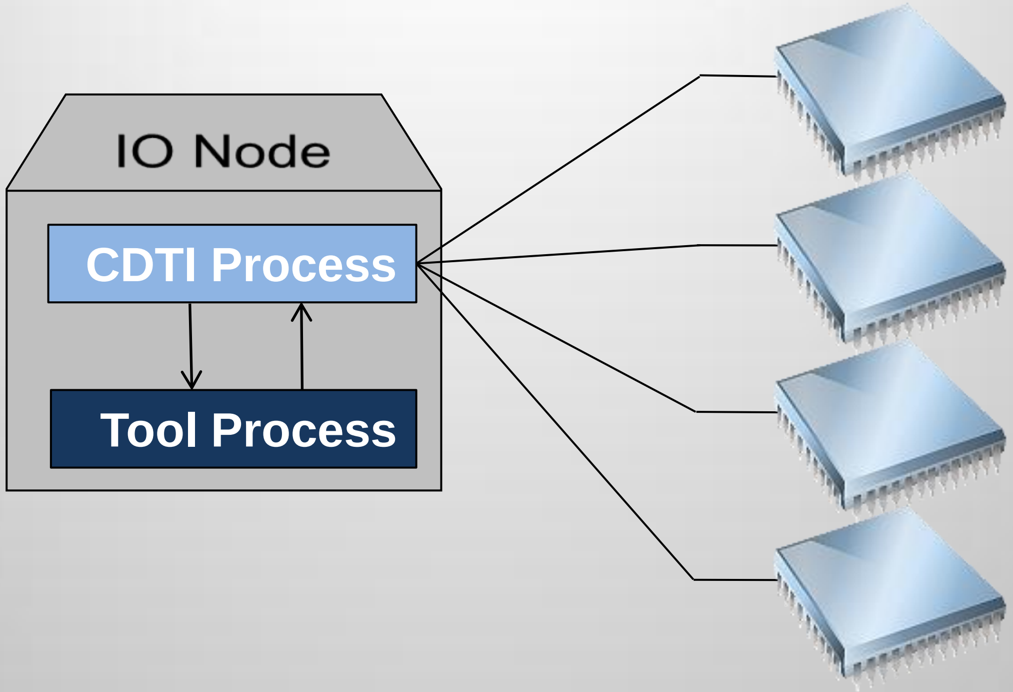
STAT showing an outliner on a hang with 393,216 cores on Sequoia.

- It took less than 5 minutes in resolving errors that occurred with 24 Sequoia racks.
- Efficient mechanisms like STAT to diagnose and to fix Sequoia development challenges are key to success.
- Co-design of various BGQ tools interfaces such as CDTI has been essential to enabling those tools on Sequoia.

CDTI – Code Development and Tools Infrastructure

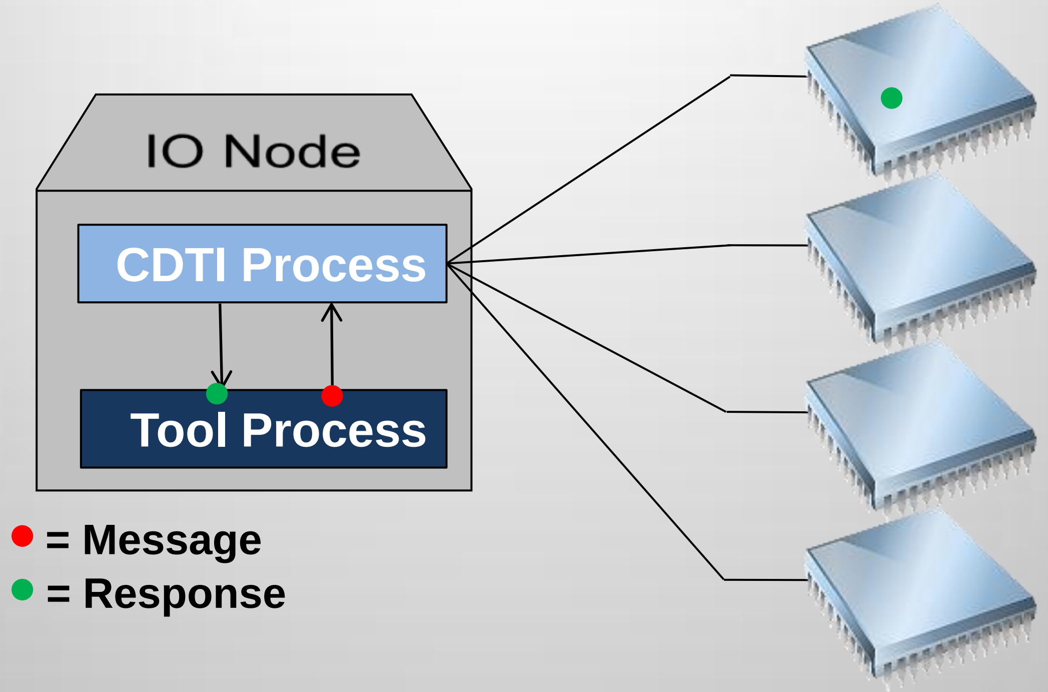
- Standard Debugging Operations
- New Types of Capabilities:
  - Scalability
  - Call Stack Unwinding
  - File IO
  - Multi-tool Support
  - Tool Launching

Architecture and Scalability



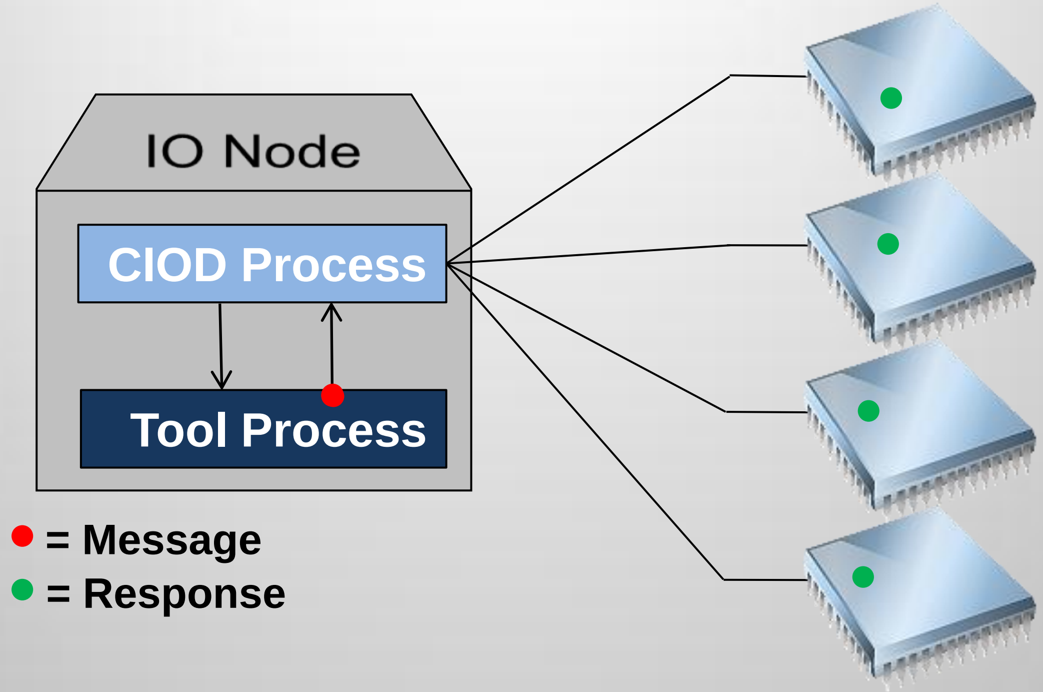
- 3rd Party Tools run on IO-Node
  - Linux
  - Network Connectivity
  - Away from application

Architecture and Scalability



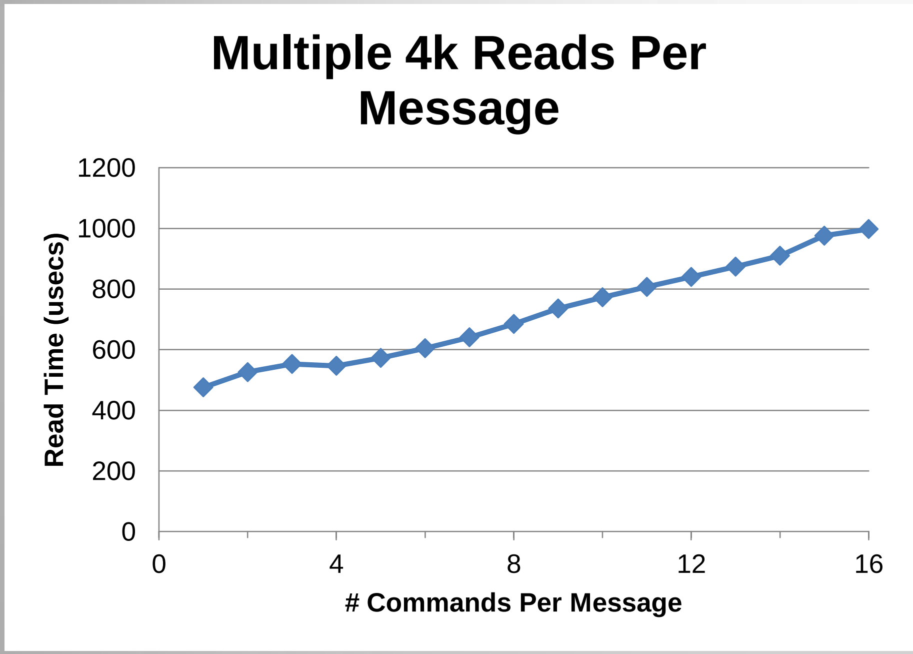
- Message Interface between Tool and CN
  - Packages 16 commands into each message
  - Commands: Debug Operations, Stackwalks, File IO, …
- Asynchronous communication

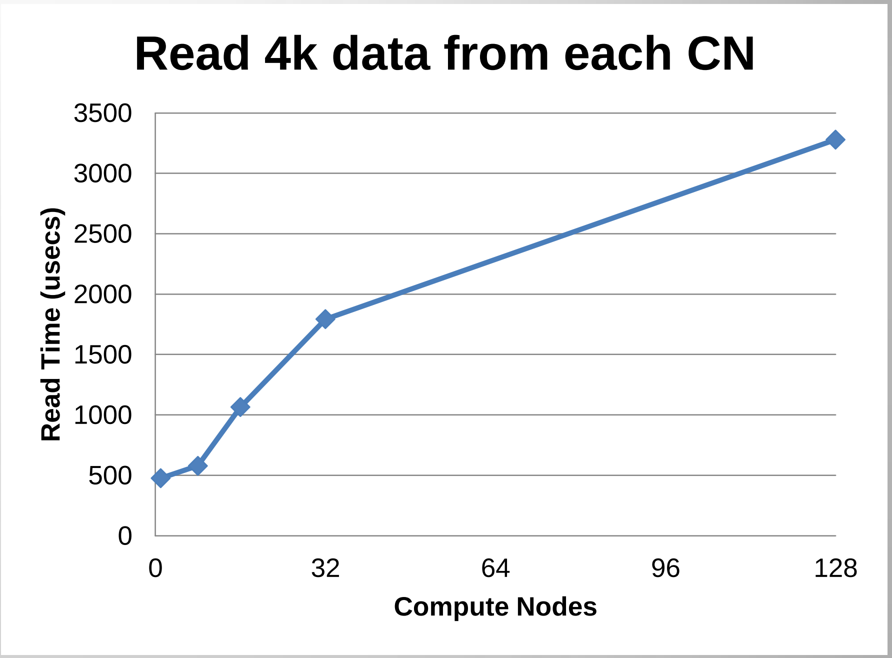
Architecture and Scalability



- Asynchronous Communication allows parallelism
  - IO Node/Process ratio: 1:2048 (common),
    1:8192 (theoretical max)

Parallel Performance





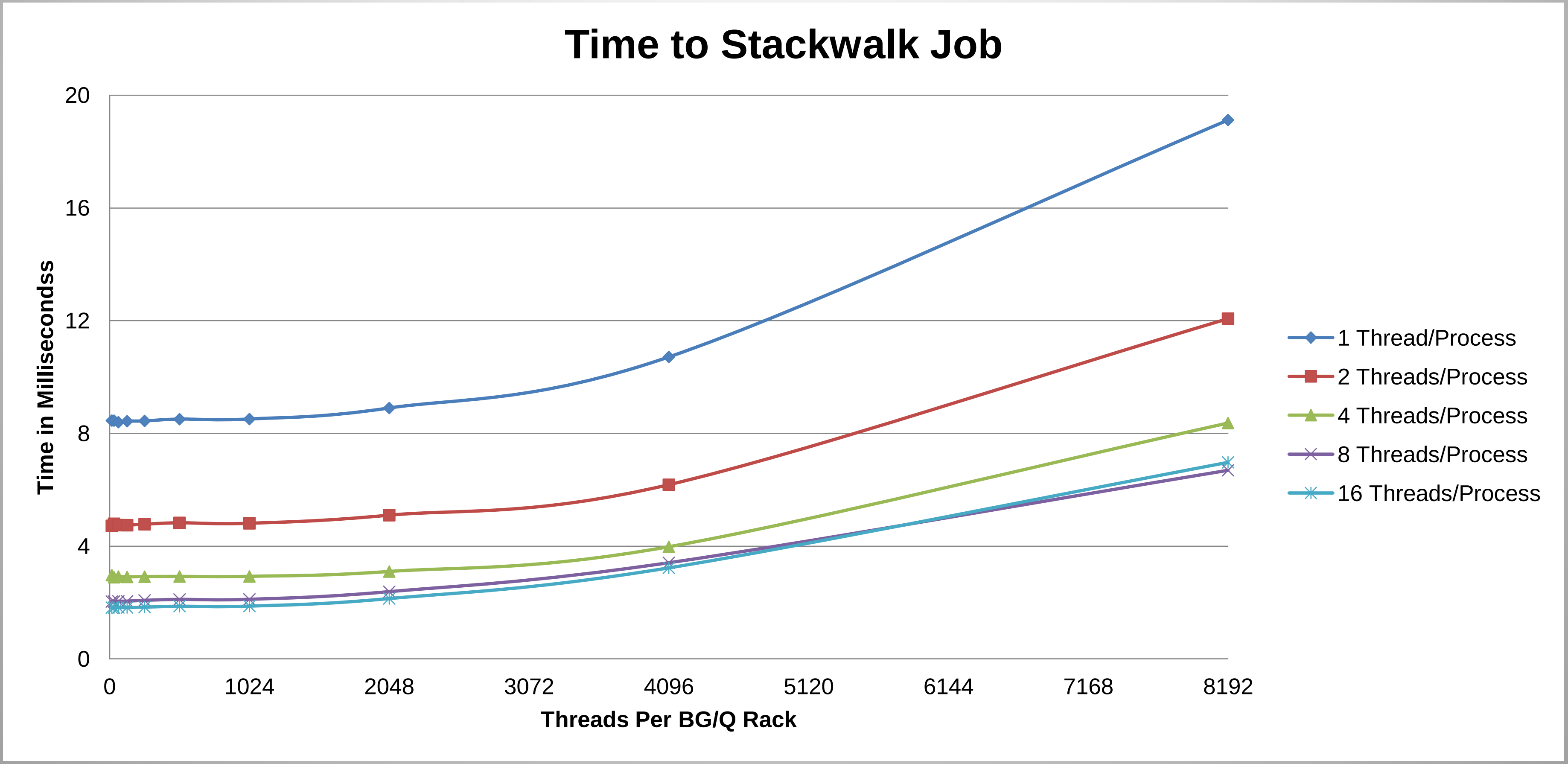
Cost to send 16 commands per message only x2 cost to send 1.

Cost to read from 128 CNs only x7 cost to read from 1 CN.

Stack Unwinding via CDTI

- Single command to collect call stack
  - CNK collects call stack, returns it via CDTI.
  - Lower latency than traditional: pause, read register, read mem, read mem, read mem, …
- Uses basic stack walking techniques
  - No DWARF or binary analysis
- Trade off: Scalability vs. Accuracy

Stack Unwinding Performance

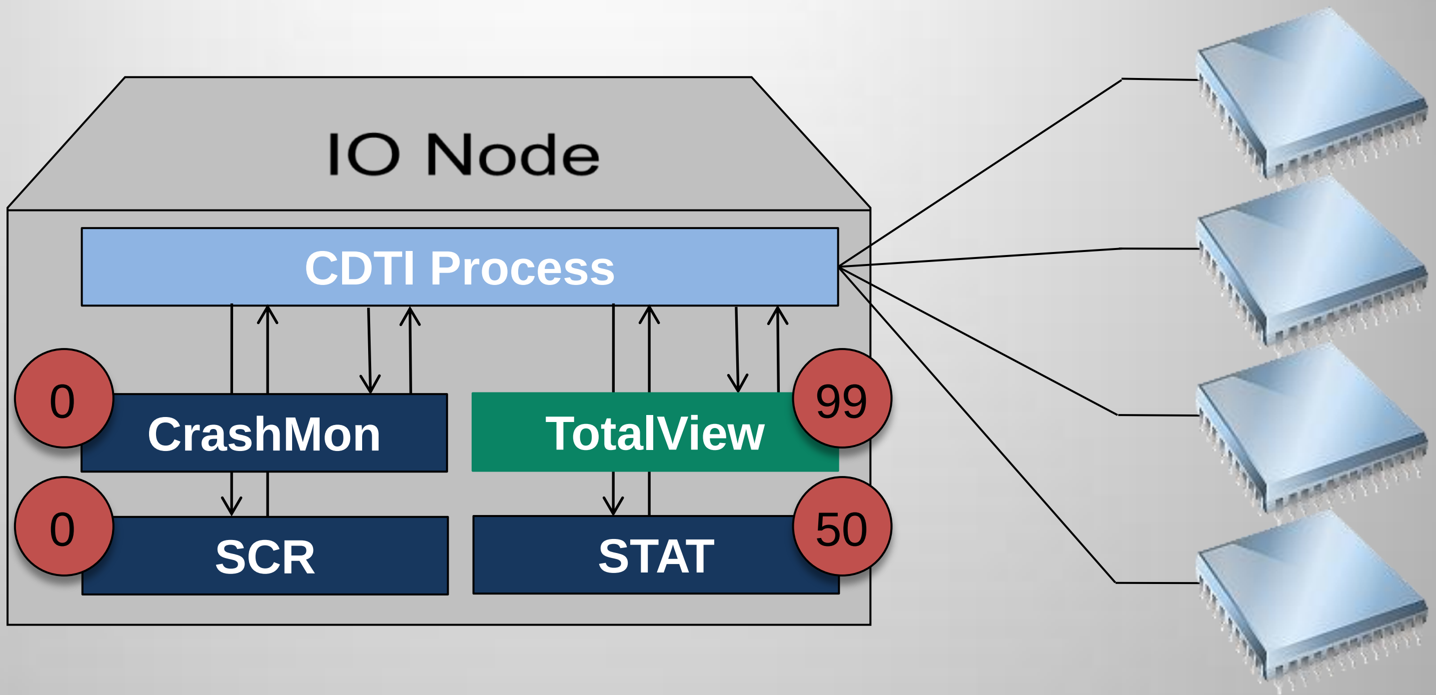


Ramdisk IO

- Asynchronous File Reads
  - Read file data, `stat` files, get directory contents.
  - Peak read speed of ~2GB/Sec

- Useful for getting data off CN's ramdisk
  - Trace data
  - Checkpoint data (current plans for SCR)

Multi-Tool Support



- Attach up to Four Tools at once
- Each Tool has Priority 0-99
  - Highest priority tool has **Control Authority**
  - Other tools have read access

Operations Available

Control Authority

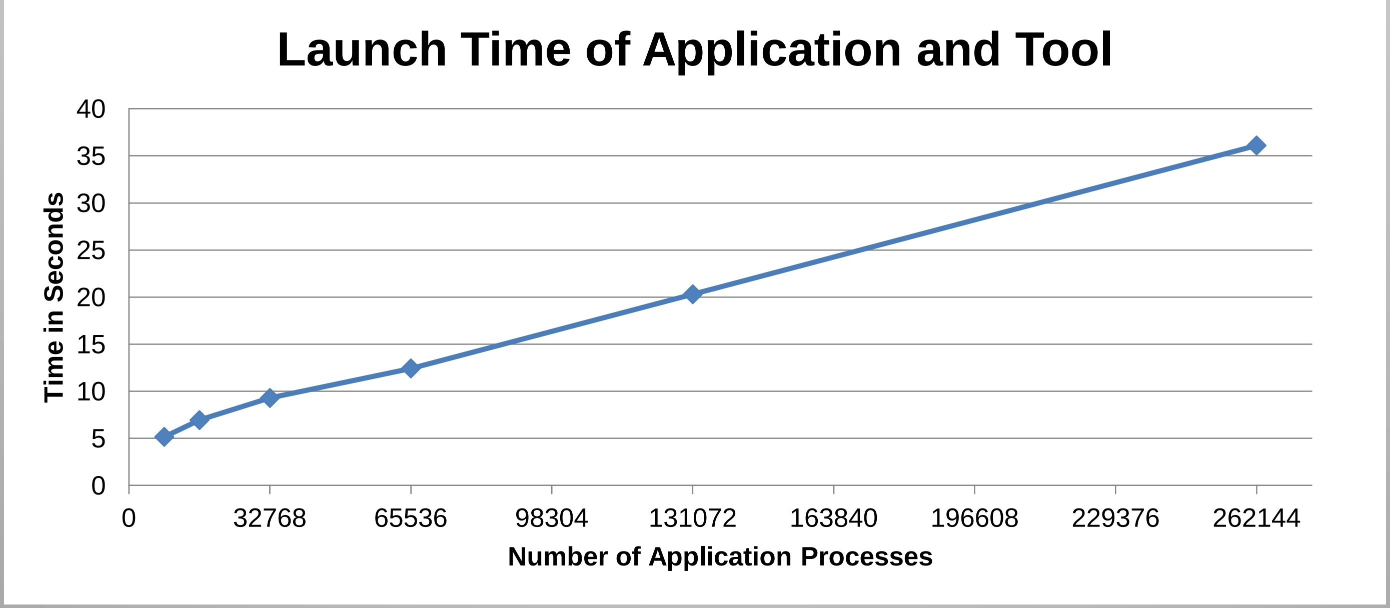
- Receive Events
- Stop/Continue Threads
- Install Breakpoints
- Allocate/Free Memory
- Send/Manage Signals
- Write Memory
- Write Registers

Read Access

- Get Thread Data (inc. Callstack)
- Get Process Data
- Ramdisk IO
- Read Memory
- Read Registers

Job Launch

- Launches Tools via MPIR and **`start_tool`**
  - MPIR provides app's process table
  - **`start_tool`** runs processes on IO-Node



CDTI Status

- Supported by ProcControlAPI and LaunchMON tool components.
- Used by TotalView
- Interface Available from IBM Redbook:

Blue Gene/Q Code Development and Tools Interface

at

http://www.redbooks.ibm.com/redpieces/abstracts/redp4659.html

Transactional Memory and Speculative Execution

- Expect shift towards threading in BG/Q

- New BG/Q Hardware Features
  - Transactional Memory
    - Synchronization mechanism, alternative to lock
  - Speculative Execution
    - Auto-parallelization of loops

Transactional Memory

- Fast Synchronization Primitive
  - Allows multiple threads into critical region
  - Dynamically detect and roll back conflicts
  - Low overhead in no conflict case
- Ideal when conflicts are non-zero, but rare.

Locks:

```
 //Remove element from list
lock()
elem = head;
head = head->next;
unlock();
```

TM:

```
//Remove element from list
#pragma tm_atomic
{
  elem = head;
  head = head->next;
}
```

Speculative Execution

- Auto-parallelize loops
  - Breaks loops into tasks
  - Runs tasks in parallel
  - Auto-detects dependencies between tasks
- Ideal when there are some conflicts, but not too many.

SE:

```
#pragma speculative for private(i) schedule (static)
for (i=0; i < num_regions; i++) {
  regions[i] = update_region(i);
}
```

SE and TM Performance Questions

- What critical sections in my code would benefit from TM?
- Are my TM regions performing well?
- What loops would benefit from SE?
- Are my SE loops performing well?

TM/SE Performance Counters

- TM/SE Counters
  - Transactions/Commits
  - Retries
  - Serializations
  - …
- Details forthcoming

Summary

- Sequoia brings in new challenges and capabilities.
  - BGQ CDTI provides new kinds of functionality for tools.
  - Need tool support for TM/SE.

- Users need our help!