High Speed Asynchronous Data Transfers on the Cray XT3

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Outline

• Data Streaming Requirements in the Fusion Simulation Project
  – Support for Code Coupling & Asynchronous Data Movement
• DART Overview
• DART Architecture and Description
• DART Evaluation
• Conclusions and Future Work
Data Streaming Requirements in the Fusion Simulation Project (FSP)

- GTC Runs on Teraflop/Petaflop Supercomputers
- Data archiving
- Data replication
- Large data analysis
- End-to-end system with monitoring routines
- 40Gbps
- User monitoring
- Data replication
- Post processing
- Visualization

- **Data Streaming Requirements**
  - Enable high-throughput, low latency data transfer to support near real-time access to the data
  - Minimize related overhead on the executing simulation
  - Adapt to network conditions to maintain desired QoS
  - Handle network failures while eliminating data loss
Support for Code Coupling & Asynchronous Data Movement

- **Seine**: Dynamic, semantically-specialized shared-spaces for code coupling
  - High-level (shared-space) programming abstractions, efficient and scalable runtime

- **DART**: Light-weight substrate for asynchronous, low-overhead/high-throughput data IO on petascale system
  - Based on Portals and RDMA

- **ADAPT**: Middleware for autonomic wide-area data streaming and in-transit data processing
  - Enable high-throughput, low latency data transfer to support near real-time access to the data
  - Effectively outsource processing to in-transit processing nodes
  - Minimize related overhead on the simulation
  - Adapt to network conditions to maintain desired QoS
DART: A Substrate for Asynchronous IO

• Objectives: Alleviate impact of IO on scientific simulations
  – Minimize total IO time on compute nodes
  – Maximize data throughput on compute nodes
  – Minimize overhead on data transfers (packet header size)
  – Minimize IO computational overhead on compute nodes
    • Data transfer logic, data buffering

• Key idea – Overlap transfers with computations

• DART Client – Runs on compute nodes
  – Lightweight & Simple!
    • maintains buffers for data transfers
    • notifies server when data is available

• DART Server – Runs on service/IO nodes
  – Contains logic and buffers
    • pulls data from compute nodes on notification
    • performs requested IO (i.e. file system, socket, etc.)

• Data transfers are asynchronous and decoupled
DART: Architecture

- Compute and Service nodes communicate using the Portals library
- Service nodes and receivers on remote cluster (i.e. Ewok) communicate using TCP sockets
The Portals Library

- RDMA implementation with OS and Application bypass
- Put operation
  - Initiator pushes its MD content into the target's address space
  - Events are recorded
- Get operation
  - Initiator fetches the target's MD content into its address space
  - Events are recorded
DART: Server Operation

TCP transfer

(Ewok)

DART Service Node

header

data

Portals "getdata"

"empty" buffer

"pending" buffer

"full" buffer

eq

1

2

3

5

6

7

8

9

10

11

12

13

Transmission Control Protocol transfer (Ewok)
DART: Time Sequence at the Client

- DART asynchronous IO calls at the client
  - Send calls return before data transfer completes
  - Data transfers overlap with computations
  - IO calls can block if buffer is full or busy
DART: Time Sequence at the Server

- Asynchronous data transfers
  - $teb$ – time spent in the “empty buffer” queue
  - $tpb$ – time spent in the “pending buffer” queue
  - $tfb$ – time spent in the “full buffer” queue
DART Evaluation: Achieved Transfer Rates

- Maximum transfer rate achieved between CN and SN on Jaguar
  - One DART server and two DART clients
  - Message sizes varied from 1 MB to 100 MB using 4 MB increments
  - Data dropped at the service node
DART Evaluation: Influence of Compute Time on IO Overhead

- **Stream time on service node**
  - Data sends are sequential ~ 3.4 sec cumulative time over 100 iterations

- **Compute time 1 microsecond**
  - No overlap – IO operation sequential

- **Optimum compute time value:** \# CN * stream time
DART Evaluation: Influence of Compute Time on IO Overhead

- Stream time on service node
  - Data sends are sequential ~ 3.4 sec cumulative time over 100 iterations

- Compute time 4.3 sec
  - Maximum overlap – IO operations parallel

- Need to balance compute time with IO time for maximum overlap
DART Evaluation: Tests Using the GTC Application

- Experiment using the GTC fusion application
  - 128 compute nodes served by 1 service node
  - A ~8.9 MB restart file/compute node written every ~4.5 sec
  - 100 simulation steps
- DART write time: ~0.12 sec
- Effective transfer rate ~593Mbps / compute node
- IO overhead on compute node 2.7%
DART Evaluation: Tests Using the GTC Application

GTC IO Time Using Lustre

GTC IO Time Using Dart
Conclusions and Future Work

• High throughput, low latency data streaming is critical for emerging scientific applications

• DART supports low overhead asynchronous IO on the Cray XT3

• DART Performance
  – Maximum achievable transfer rates using Portals
    • Two clients and one server
  – Overhead of IO operations on GTC application
    • Restart files ~ 8.9 MB/node

• Future work
  – Extend DART to support large message sizes
    • Integrate with GTC to enable ~160 MB/node restart files
  – Enable N x M x P coupling on top of DART
Questions

Thank You!