HPC ADVISORY COUNCIL

ANSYS FLUENT 13
Performance Benchmark and Profiling

April 2011

AMD The future is fusion

DELL

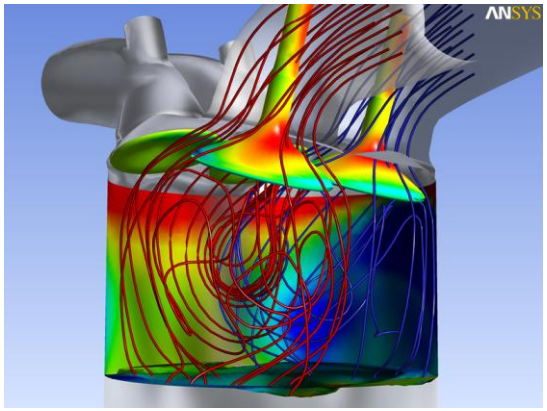
Mellanox TECHNOLOGIES

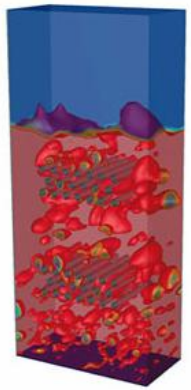
Note

- **The following research was performed under the HPC Advisory Council activities**
  - Participating vendors: AMD, Dell, Mellanox
  - Compute resource - HPC Advisory Council Cluster Center
- **For more info please refer to**
  - http:// www.amd.com
  - http:// www.dell.com/hpc
  - http://www.mellanox.com
  - http://www.ansys.com

CFD and ANSYS FLUENT

- **Computational Fluid Dynamics (CFD) is a computational technology**
  - Enables the study of the dynamics of things that flow
    - By generating numerical solutions to a system of partial differential equations which describe fluid flow
  - Enable better understanding of qualitative and quantitative physical phenomena in the flow which is used to improve engineering design
- **CFD brings together a number of different disciplines**
  - Fluid dynamics, mathematical theory of partial differential systems, computational geometry, numerical analysis, Computer science
- **ANSYS FLUENT is a leading CFD application from ANSYS**
  - Widely used in almost every industry sector and manufactured product





Objectives

- **The following was done to provide best practices**
  - ANSYS FLUENT performance benchmarking
  - Interconnect performance comparisons
  - CPU performance
  - Understanding FLUENT communication patterns
  - Ways to increase FLUENT productivity
  - MPI libraries comparisons

- **The presented results will demonstrate**
  - The scalability of the compute environment
  - The capability of FLUENT to achieve scalable productivity
  - Considerations for performance optimizations

Test Cluster Configuration

- **Dell™ PowerEdge™ R815 11-node (528-core) cluster**
- **AMD™ Opteron™ 6174 (code name "Magny-Cours") 12-cores @ 2.2 GHz CPUs**
- **4 CPU sockets per server node**
- **Mellanox ConnectX-2 VPI adapters for 40Gb/s QDR InfiniBand and 10Gb/s Ethernet**
- **Mellanox MTS3600Q 36-Port 40Gb/s QDR InfiniBand switch**
- **Fulcrum based 10Gb/s Ethernet switch**
- **Memory: 128GB memory per node DDR3 1333MHz**
- **OS: RHEL 5.5, MLNX-OFED 1.5.2 InfiniBand SW stack**
- **MPI: Platform MPI 7.1**
- **Application: ANSYS FLUENT version 13.0.0**
- **Benchmark workload:**
  - sedan_4m (External Aerodynamics Flow Over a Passenger Sedan)
  - truck_poly_14m (External Flow Over a Truck Body with a Polyhedral Mesh)

Dell™ PowerEdge™ R815 11-node cluster

- **HPC Advisory Council Test-bed System**

- **New 11-node 528 core cluster - featuring Dell PowerEdge™ R815 servers**
  - Replacement system for Dell PowerEdge SC1435 (192 cores) cluster system following 2 years of rigorous benchmarking and product EOL
    - System to be redirected to explore HPC in the Cloud applications

- **Workload profiling and benchmarking**
  - Characterization for HPC and compute intense environments
  - Optimization for scale, sizing and configuration and workload performance
  - Test-bed Benchmarks
    - RFPs
    - Customers/Prospects, etc
  - ISV & Industry standard application characterization
  - Best practices & usage analysis

About Dell PowerEdge™ Platform Advantages

Best of breed technologies and partners

Combination of AMD™ Opteron™ 6100 series platform and Mellanox ConnectX InfiniBand on Dell HPC

Solutions provide the ultimate platform for speed and scale

- Dell PowerEdge R815 system delivers 4 socket performance in dense 2U form factor
- Up to 48 core/32DIMMs per server – 1008 core in 42U enclosure

Integrated stacks designed to deliver the best price/performance/watt

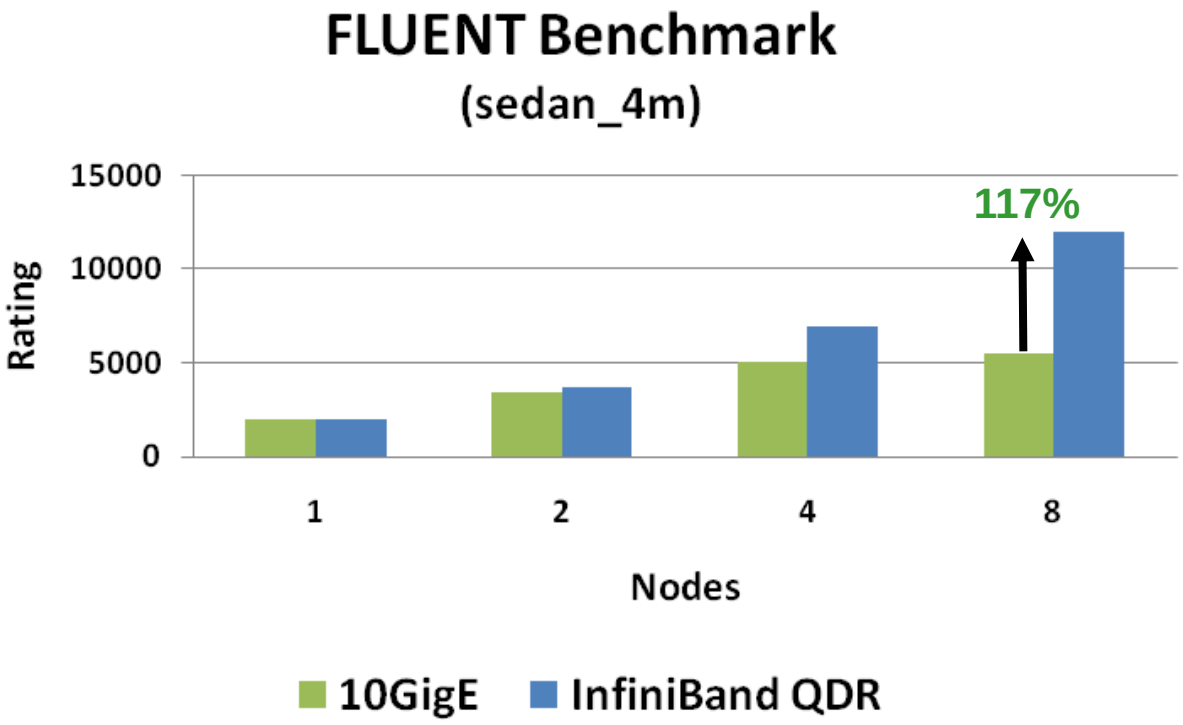
- 2x more memory and processing power in half of the space
- Energy optimized low flow fans, improved power supplies and dual SD modules

Optimized for long-term capital and operating investment protection

- System expansion
- Component upgrades and feature releases

FLUENT Performance – Interconnects

- **Dataset: sedan_4m**
  - External Flow Over a Passenger Sedan
  - 3.6 million cells of mixed type, k-epsilon model, pressure-based coupled solver
- **InfiniBand shows continuous gain as the cluster scales**
  - Up to 117% higher performance than 10GigE

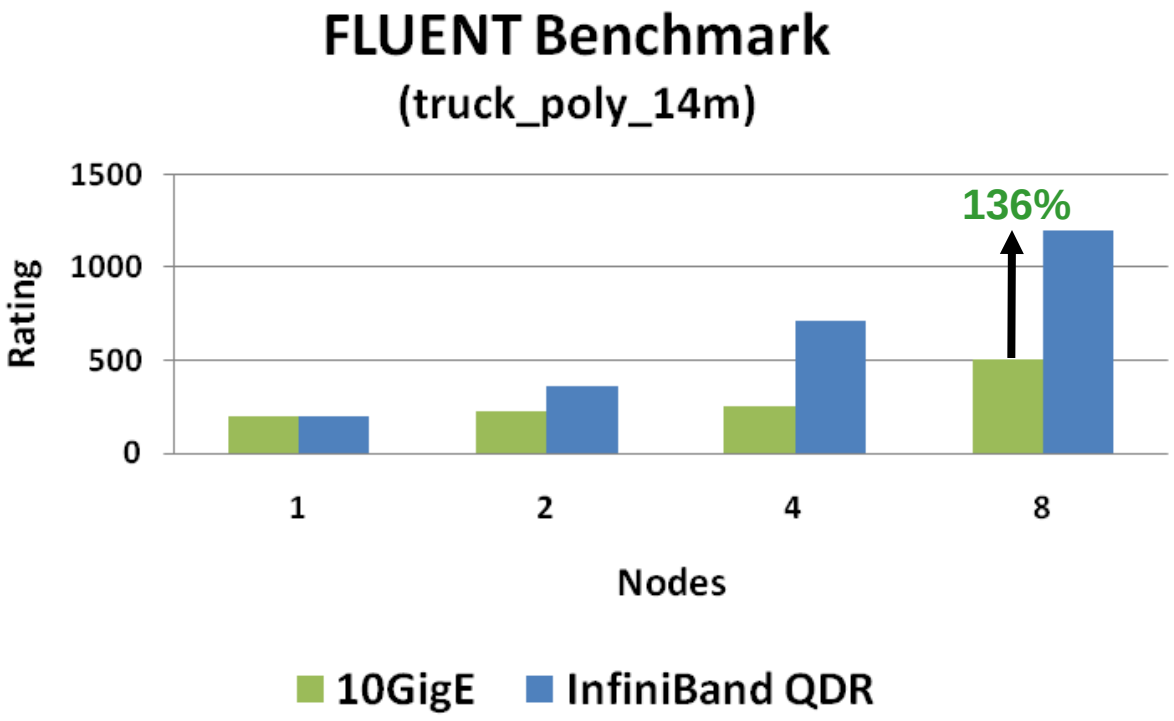


Higher is better

48 Cores/Node

FLUENT Performance – Interconnects

- **Dataset: truck_poly_14m**
  - External Flow Over a Truck Body with a Polyhedral Mesh
  - 14 million polyhedral cells, DES model with the segregated implicit solver
- **InfiniBand shows continuous gain as the cluster scales**
  - Up to 136% higher performance than 10GigE

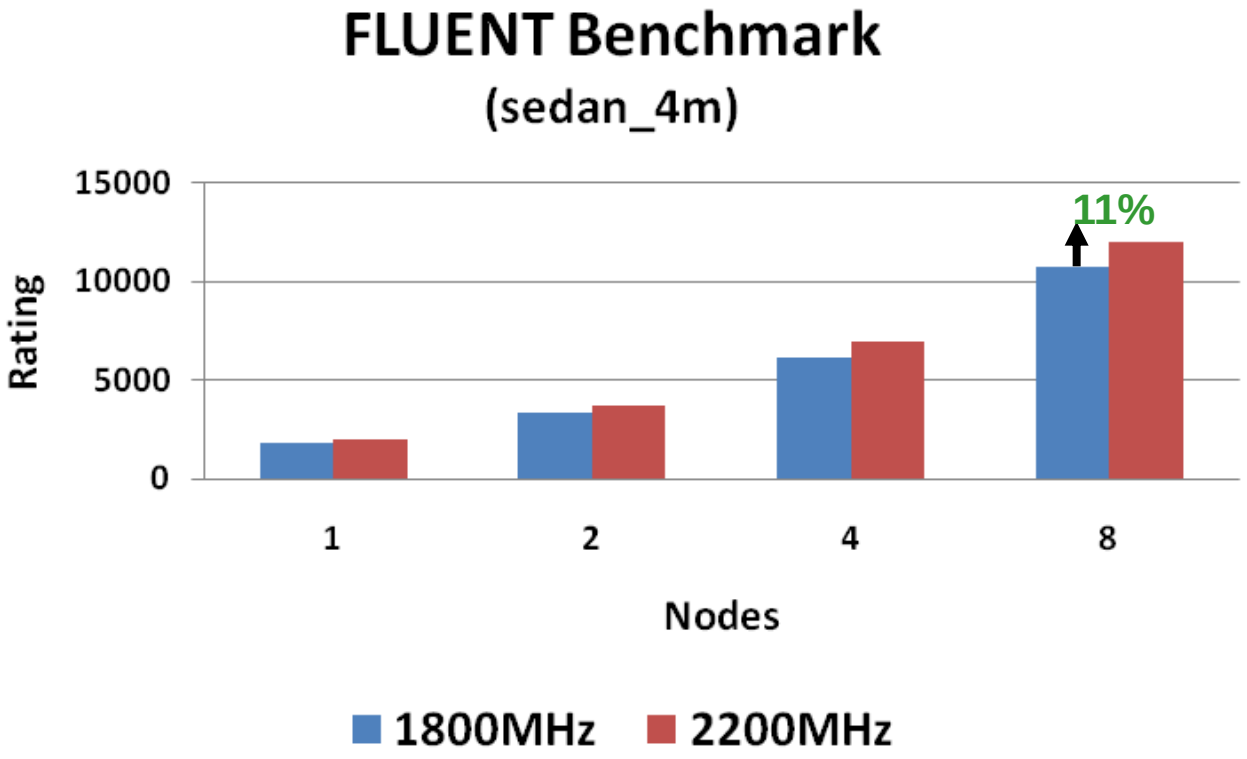


Higher is better

48 Cores/Node

FLUENT Performance – CPU Frequency

- **Increasing CPU core frequency enables higher job efficiency**
  - Up to 11% better job performance between 2200MHz vs 1800MHz on 8-node
  - Delivers a gain of 10-13% on average in better job performance

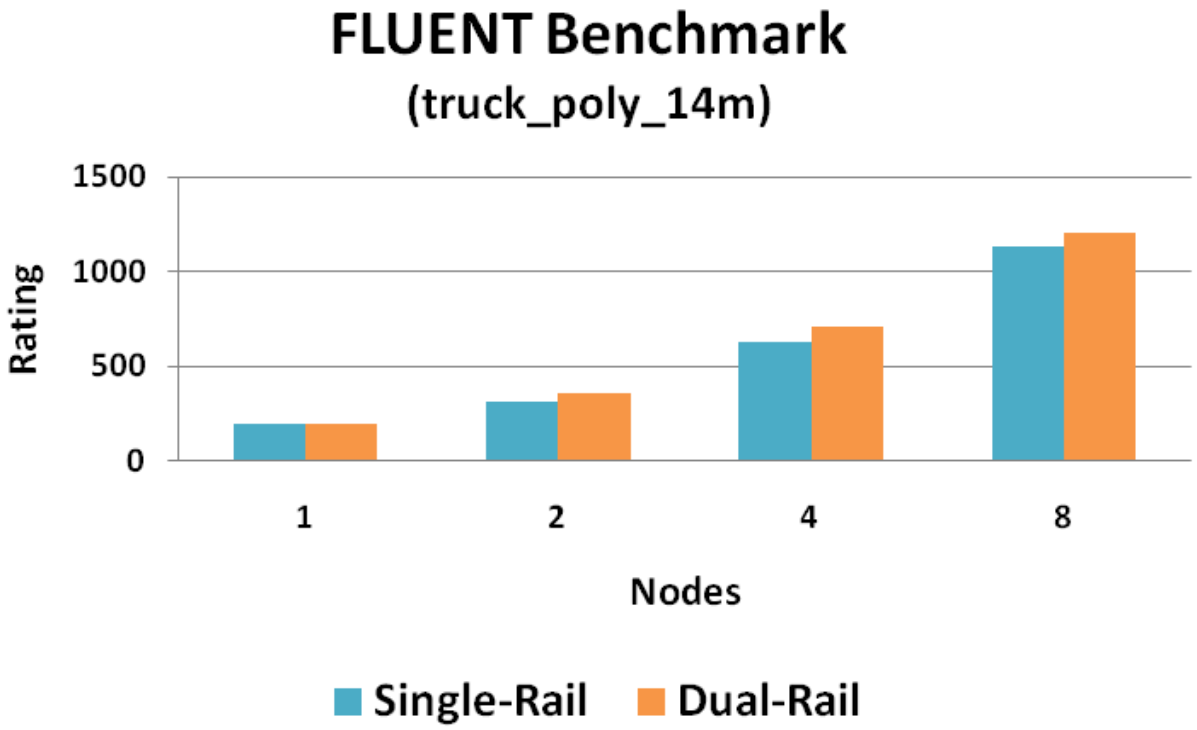


Higher is better

48 Cores/Node

FLUENT Performance – Single vs Dual Rail

- **Dual-rail (Dual InfiniBand cards) enables better performance than single-rail**
  - Up to 15% better job performance when equipped with 2 InfiniBand cards per node
  - Delivers network bandwidth that requires for data communications

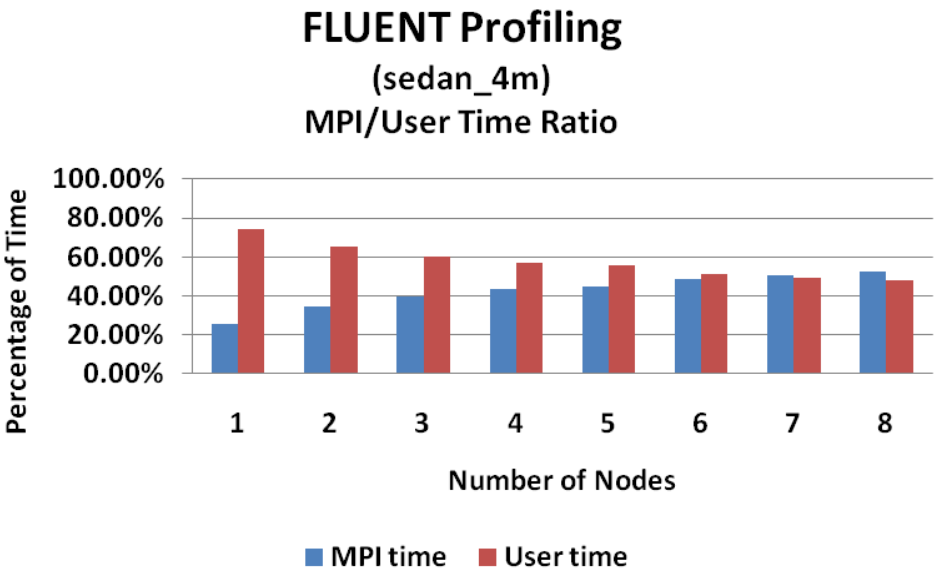


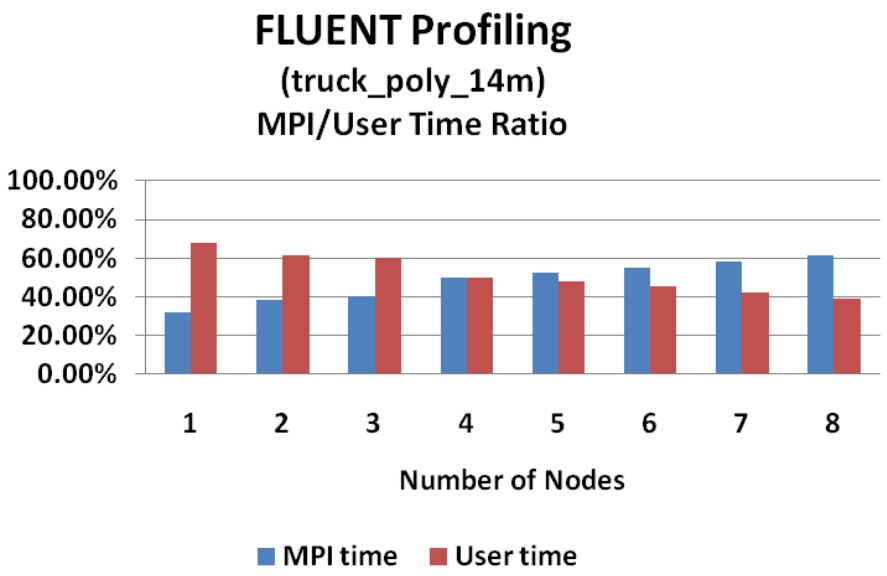
Higher is bet

48 Cores/Node

FLUENT Profiling – MPI/User Time Ratio

- **Gradual increase in communications time as the cluster scales**
  - More time is spent on communications than computation after 6-node in sedan_4m
  - More time is spent on communications than computation after 4-node in truck_poly_14m

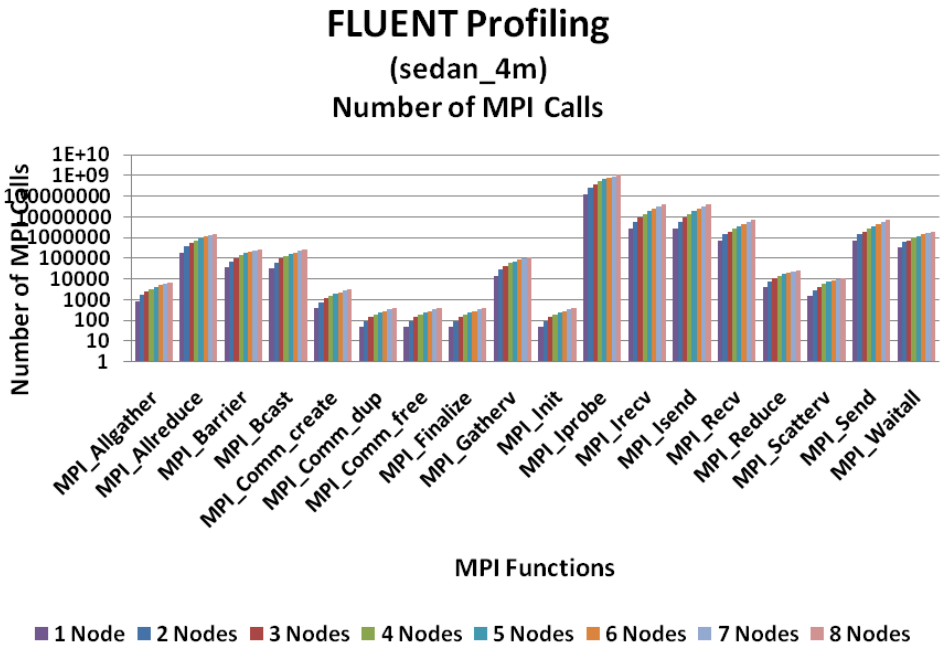


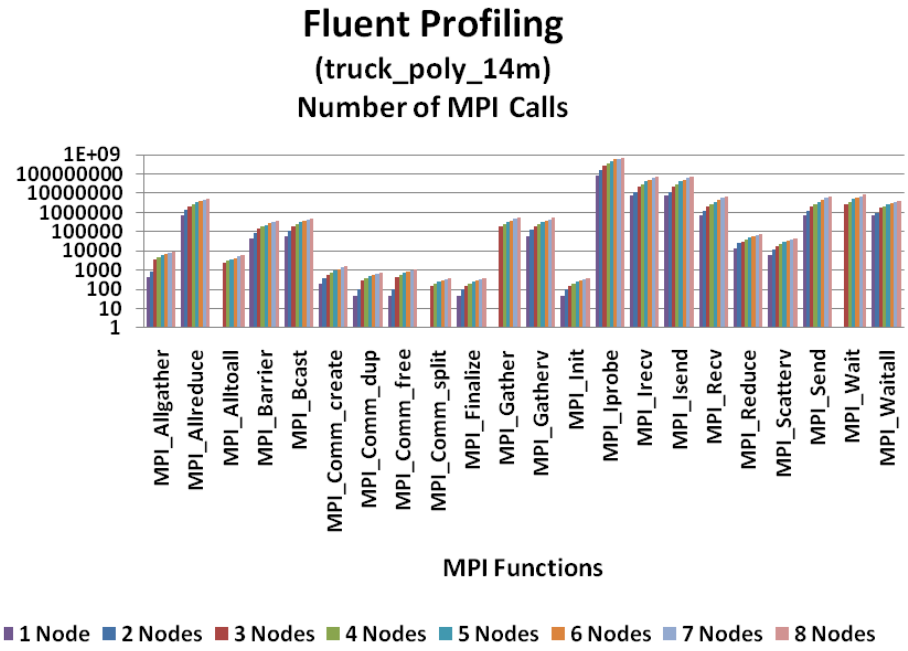


48 Cores/Node

FLUENT Profiling – Number of MPI Calls

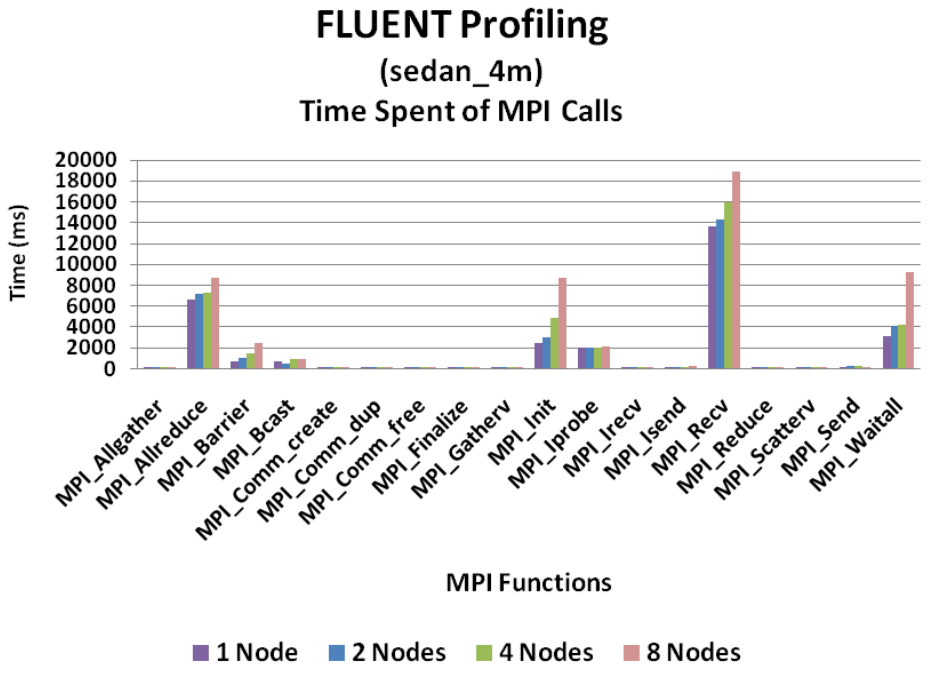
- **The most used MPI function is MPI_Iprobe**
  - MPI_Iprobe does non-blocking test for a message
  - Represents 92% of MPI calls used for 8-node in sedan_4m, 82% in truck_poly_14m
- **FLUENT uses a full range of MPI calls**
  - For blocking, non-blocking and point-to-point and collective communications
- **Data communications increases for larger dataset**
  - MPI_Irecv and MPI_Isend at a higher rate for truck_poly_14m

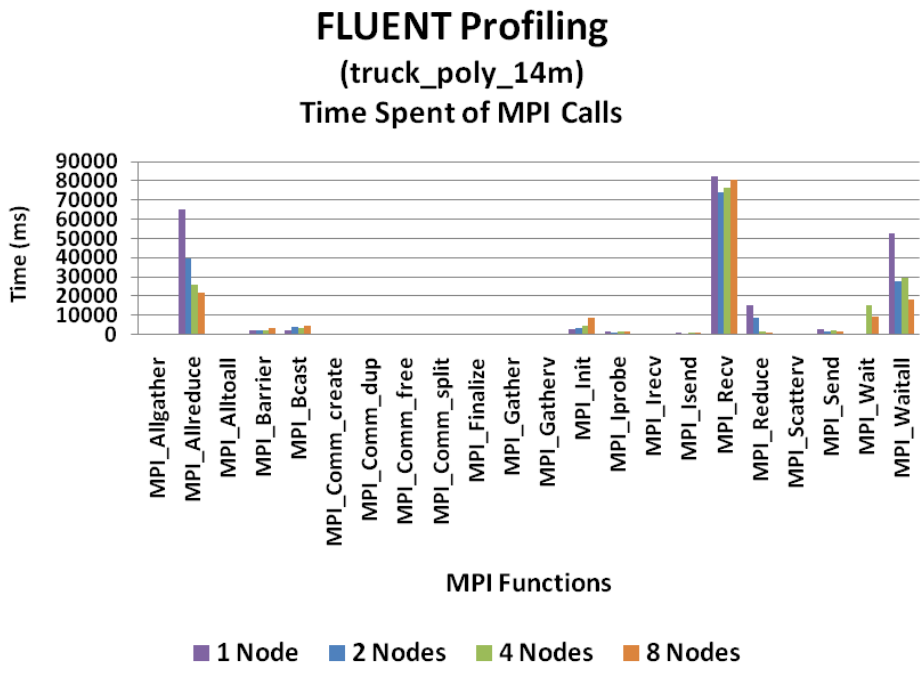




FLUENT Profiling – Time Spent of MPI Calls

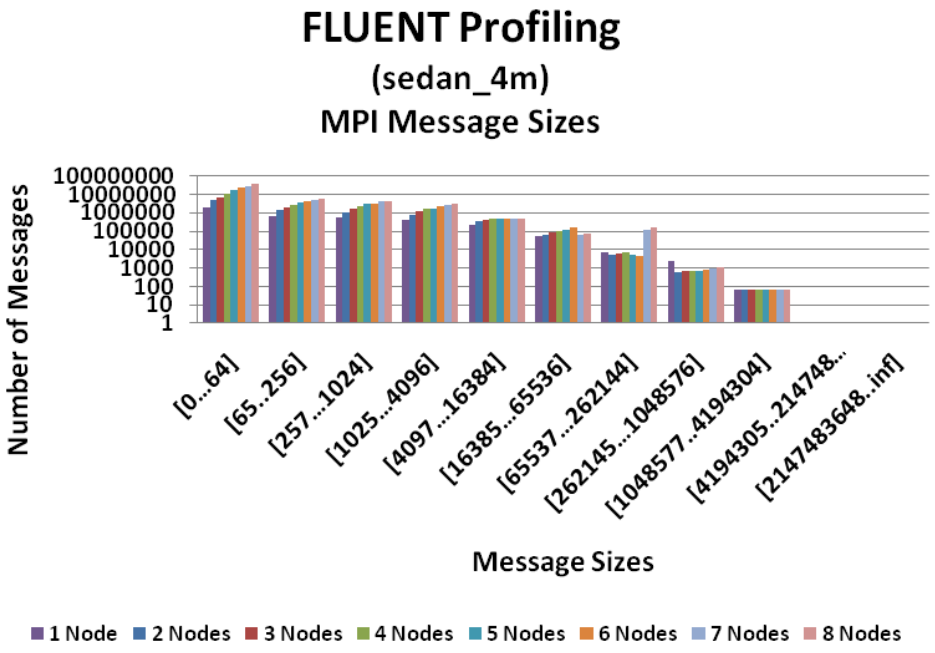
- **The largest time consumer is MPI_Recv for data communications**
  - Occupies 37% of all MPI time for 8 node in sedan_4m
  - Occupies 53% of all MPI time for 8 node in truck_poly_14m
- **The next largest time consumer are MPI_Waitall and MPI_Allreduce**
  - MPI_Allreduce(17%) and MPI_Waitall(18%) for 8 node in sedan_4m
  - MPI_Waitall(14%) and MPI_Allreduce(12%) for 8 node in truck_poly_14m
- **More time spent on data MPI communication than MPI synchronization**

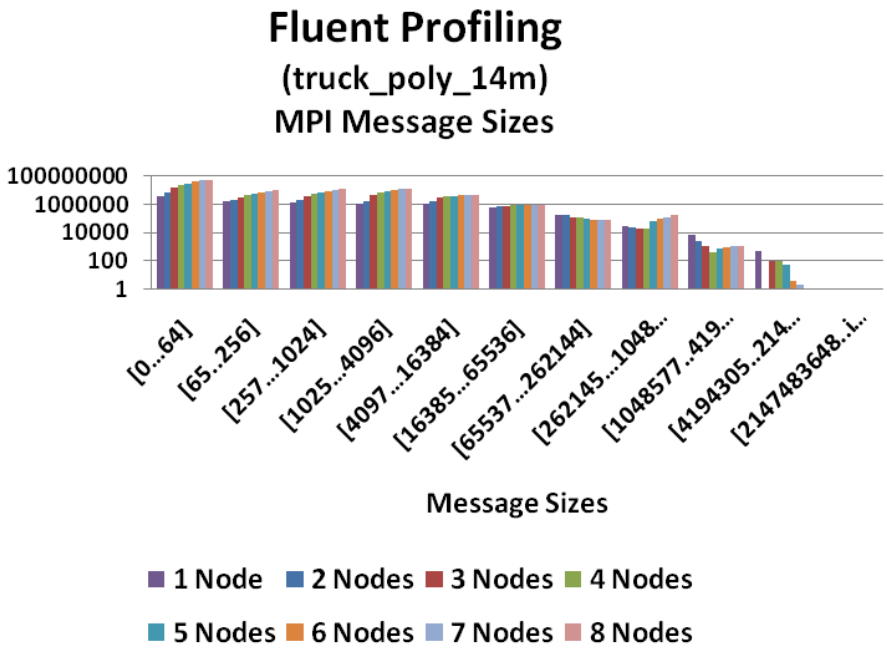




FLUENT Profiling – MPI Message Sizes

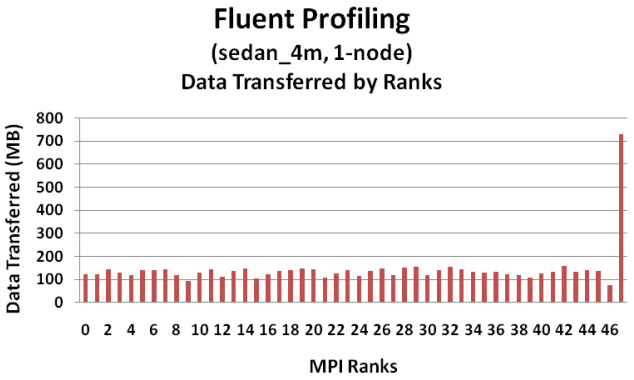
- **MPI message sizes are concentrated in range of small message sizes**
  - Majority are in the range of 0B and 64B
  - Small messages are typical used for synchronization, implies FLUENT is latency sensitive
- **Larger message sizes also appeared but at a smaller percentage**
  - Larger messages (65B to 4MB) responsible for data transfers between the MPI ranks
  - Implies that FLUENT also requires high network throughput

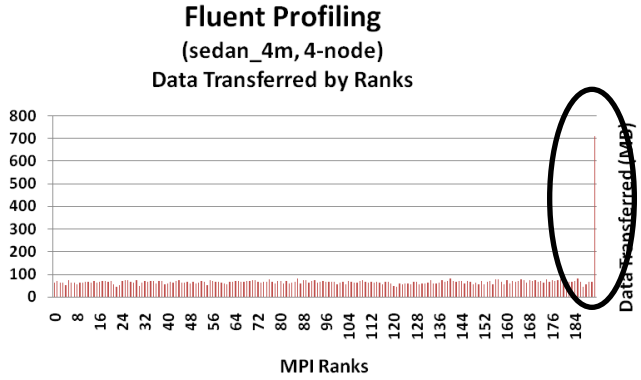


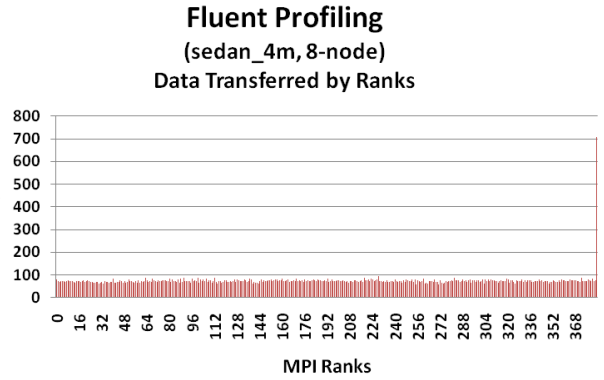


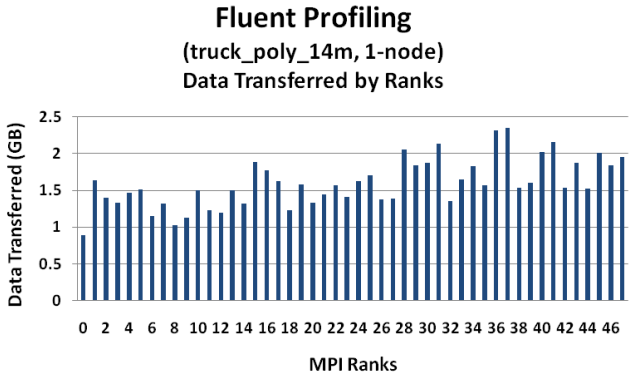
FLUENT Profiling – Data Transfer Per Process

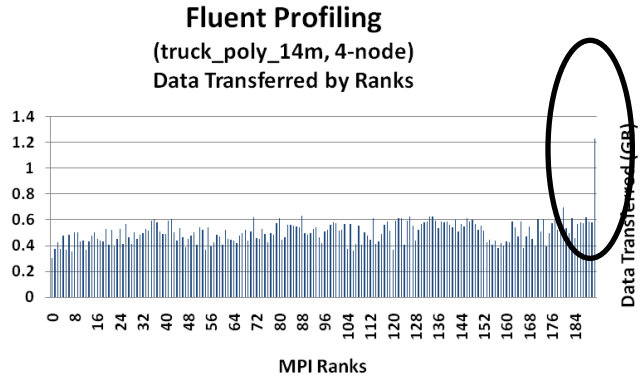
- **Data transferred to each MPI rank is generally the same except for the last**
  - Around 450MB per MPI rank for truck_poly_14m, and 100MB for sedan_4m,
  - The last MPI rank has a significantly higher data rate than the rest
- **As the cluster scales, data transfers remains generally to the same level**

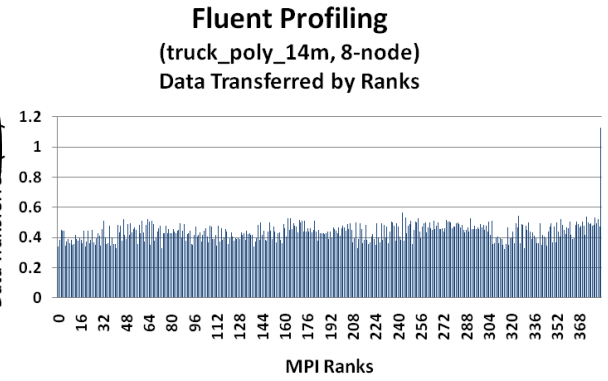






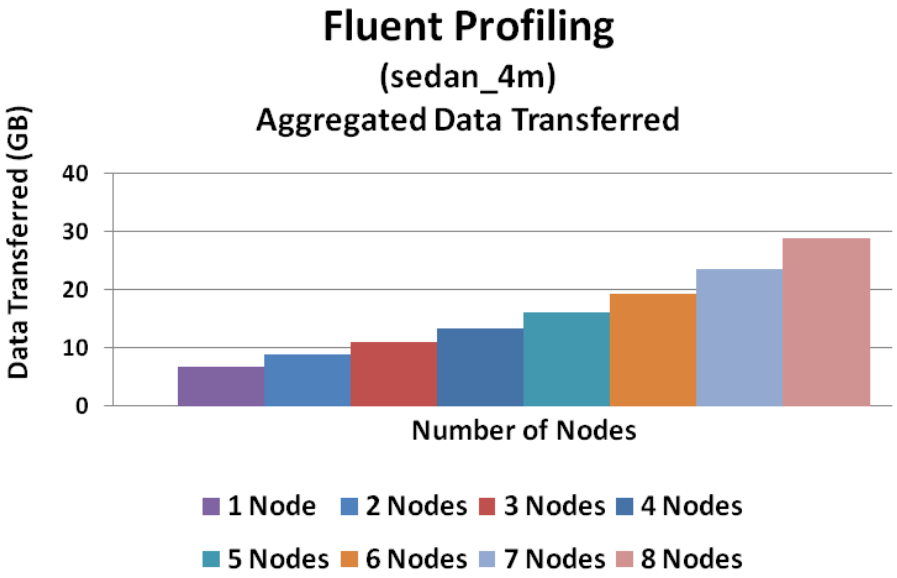


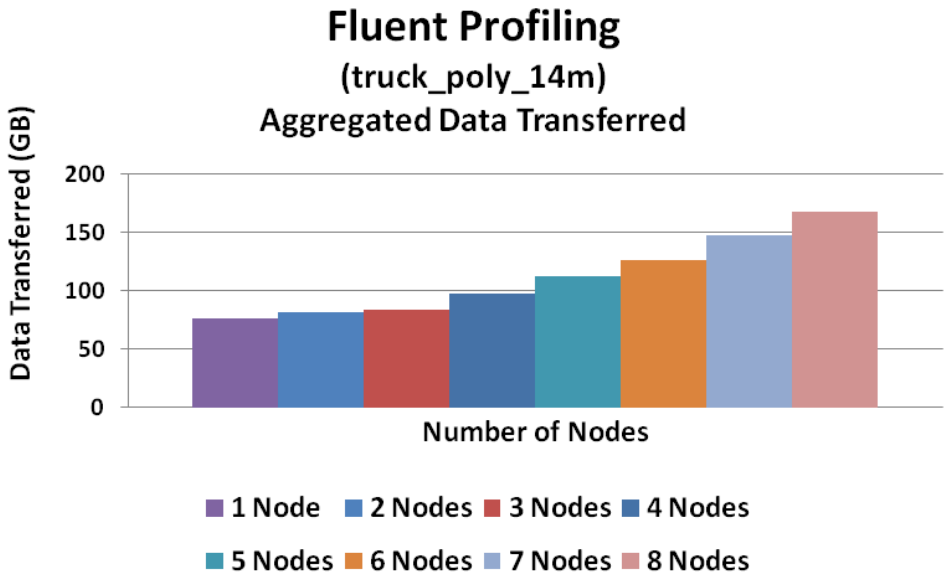




FLUENT Profiling – Aggregated Data Transfer

- **Aggregated data transfer refers to:**
  - Total amount of data being transferred in the network between all MPI ranks collectively
- **The total data transfer steadily increases as the cluster scales**
  - As a compute node being added, more data communications will happen
- **Significantly more communications happen for larger dataset**





InfiniBand QDR

Summary

- **FLUENT is a leading CFD application from ANSYS**
- **Networking**
  - InfiniBand QDR allows FLUENT to scale as it provides low latency and high throughput
  - Dual rail (two adapters) can increase the performance by 15% on a 4 socket server
- **CPU**
  - Shows gains in job productivity by using higher CPU frequency
- **Data transfer on the network**
  - Significantly more data being transferred for the larger dataset
  - Tends to increase steadily as cluster scales
- **MPI**
  - Shows FLUENT uses a range of MPI API for communications and synchronizations

Thank You

HPC Advisory Council