

Computational Fluids Dynamics (CFD) Simulations at Scale

OpenFOAM open source applications

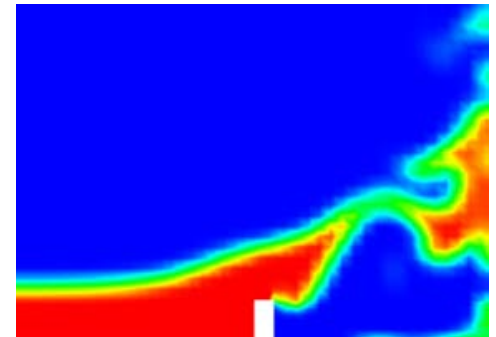
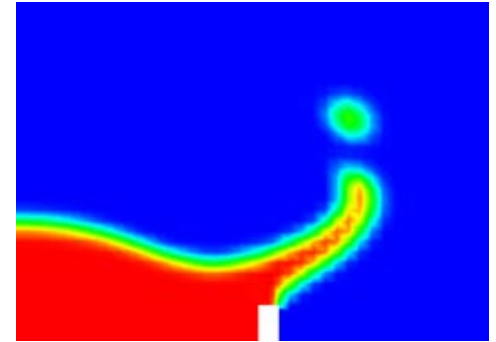
HPC|Scale Working Group, Sep 2010

- **The following research was performed under the HPC Advisory Council HPC|Scale working group:**
 - CFD simulation performance at scale
 - Using OpenFOAM application
 - The effect of non-blocking vs blocking network configurations
 - Scalability comparison between networking technologies
 - InfiniBand DDR
 - InfiniBand QDR non-blocking configuration
 - InfiniBand QDR 2:1 blocking configuration
 - Cray XT5

- **OpenFOAM® (Open Field Operation and Manipulation) CFD**

Toolbox can simulate

- Complex fluid flows involving
 - Chemical reactions
 - Turbulence
 - Heat transfer
- Solid dynamics
- Electromagnetics
- The pricing of financial options

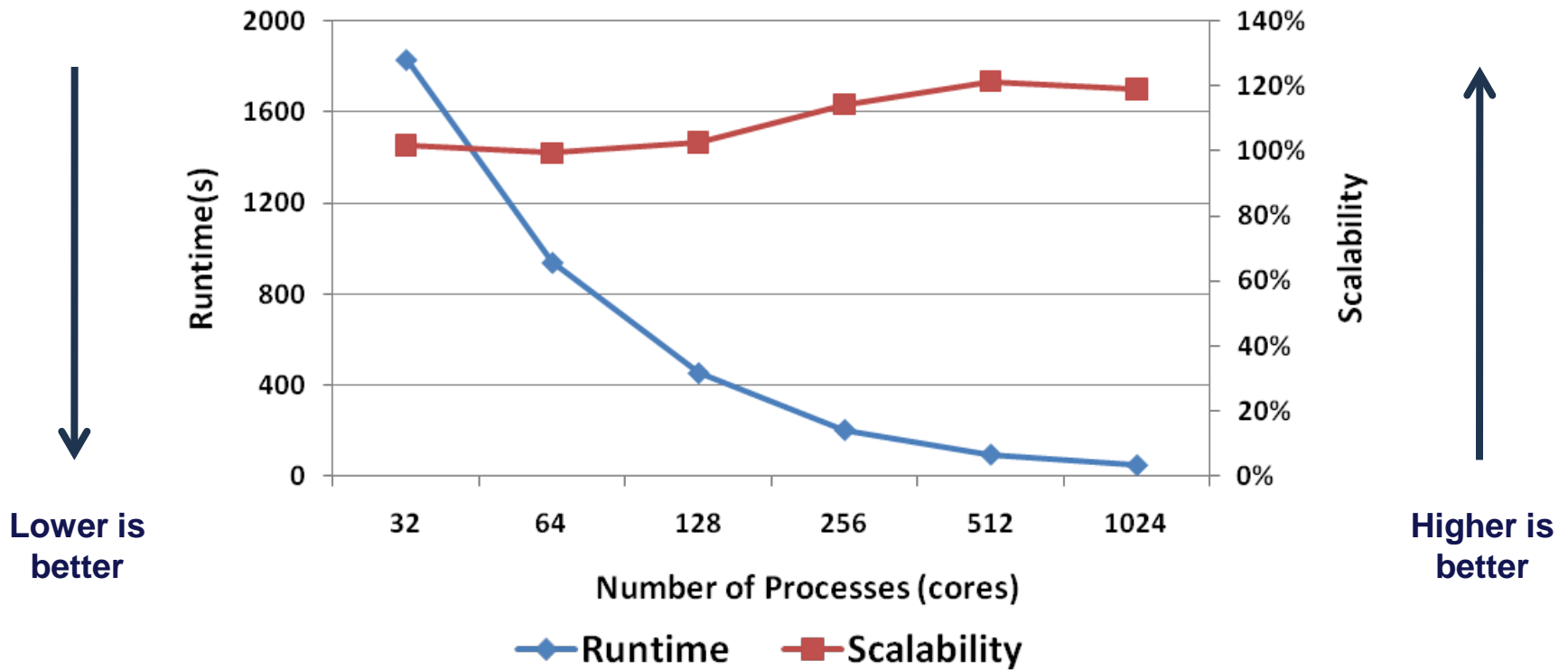


- **OpenFOAM is Open source, produced by OpenCFD Ltd**

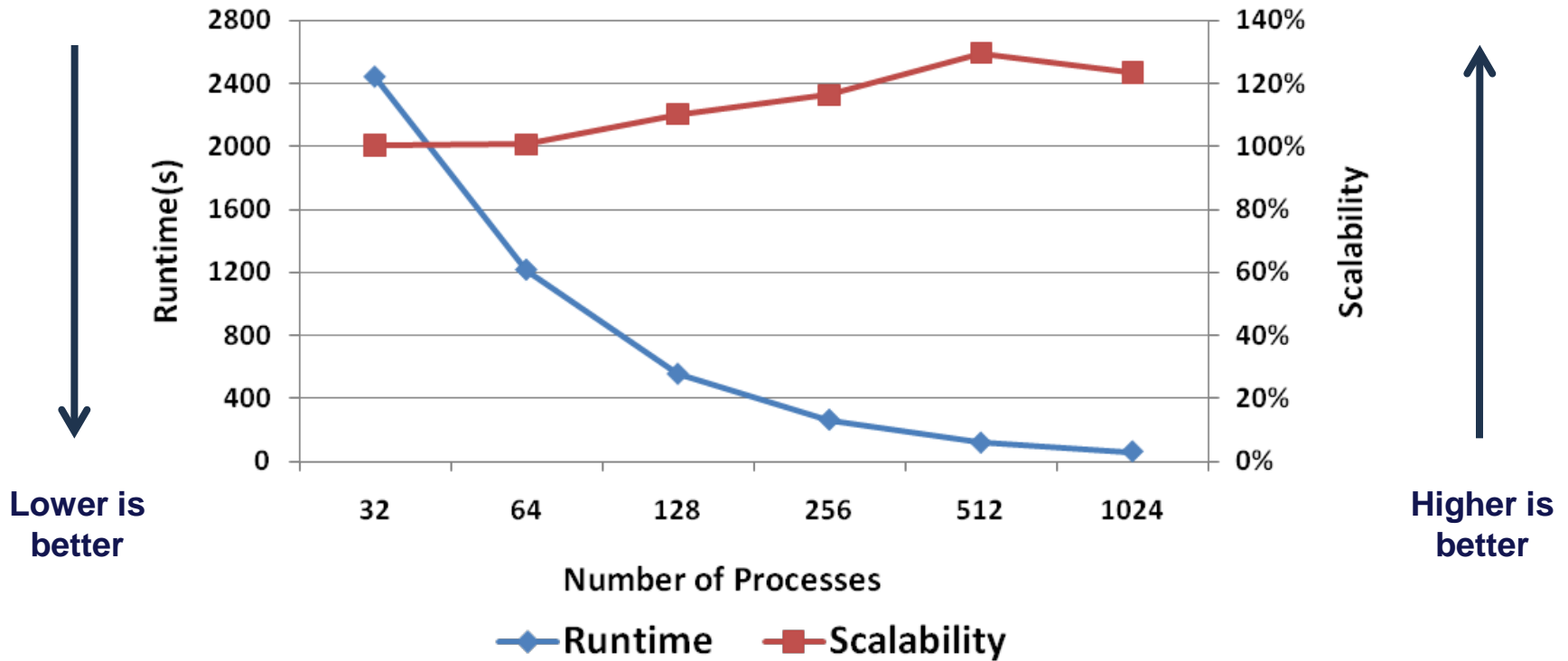
- **JuRoPa supercomputer at the Jülich Supercomputing Centre**
 - Dual socket Intel Xeon X5570 quad-core @2.93 GHz
 - 24 GB memory (DDR3, 1066 MHz)
 - Mellanox InfiniBand QDR, non-blocking network configuration
 - SUSE SLES 11
 - ParTec MPI
- **Itasca supercomputer at the Minnesota Supercomputing Institute**
 - HP ProLiant BL280c G6 blade servers
 - Dual socket Intel Xeon X5560 quad-core @2.80 GHz
 - Mellanox InfiniBand QDR, 2:1 blocking network configuration
 - SUSE SLES 11
 - OpenMPI-1.4.2, Platform MPI 2.7.1
- **Application**
 - OpenFOAM 1.7.1
 - Benchmark Dataset: Laminar Cavity Flow (2D, 16Million Cells)

- **Murska supercomputer at CSC**
 - HP CP4000 BL ProLiant supercluster
 - Dual socket dual-core 2.6GHz AMD Opteron 64-bit CPUs
 - Mellanox InfiniBand DDR, non-blocking network
- **Louhi supercomputer at CSC**
 - Cray XT5 Massively Parallel Processor (MPP) supercomputer
 - Dual socket quad-core AMD 2.3GHz AMD Opteron 64-bit CPUs
 - RHEL 4 Linux operating systems
- **The reference environment are only used for scalability comparisons, and not for performance comparison**

OpenFOAM 1.7.1 Performance (JuRoPa) (Laminar Cavity Flow Benchmark)

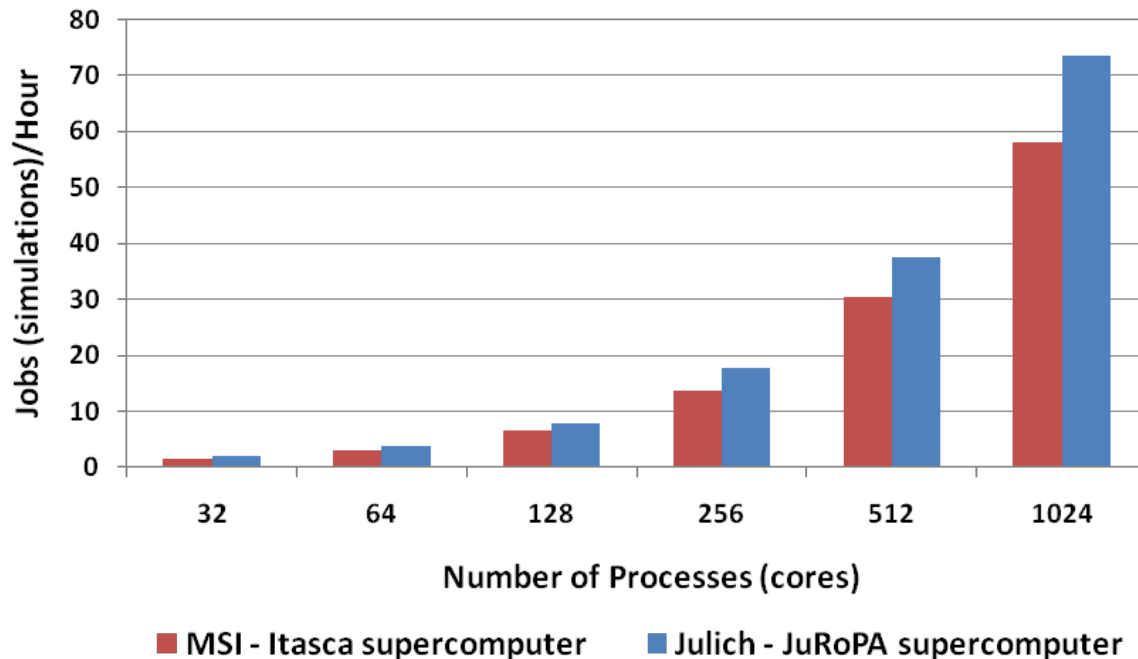


OpenFOAM 1.7.1 Performance (Itasca) (Laminar Cavity Flow Benchmark)



- **Non-blocking InfiniBand network provides ~27% higher performance versus 2:1 network blocking configuration**

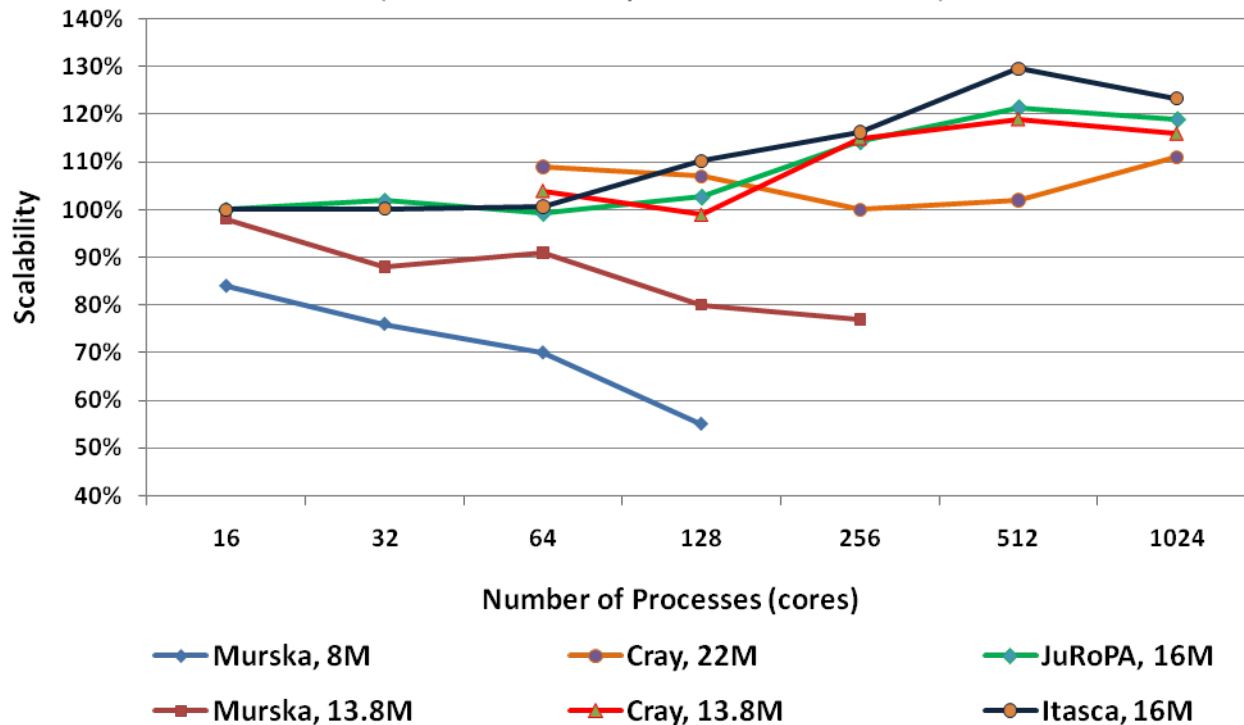
OpenFOAM 1.7.1 Performance
(Laminar Cavity Flow Benchmark)



Scalability Comparison

- **InfiniBand QDR delivers highest scalability**
 - Versus Cray XT5, and versus InfiniBand DDR
 - Murska – IB DDR, JuRoPa and Itasca – IB QDR

OpenFOAM 1.7.1 Performance
(Laminar Cavity Flow Benchmark)



- **OpenFoam demonstrates good scaling capabilities**
 - Testing includes systems configuration up to 1K cores
- **For OpenFOAM, non blocking network delivers higher performance compared to 2:1 blocking configuration**
 - 27% higher performance in average
- **InfiniBand QDR demonstrates highest scalability**
 - Compared to Cray XT5 and InfiniBand DDR

Thank You

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