Accelerating HPC and DL Applications Using MVAPICH2-DPU Library and X-ScaleAI Package

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http://x-scalesolutions.com
Outline

• **Overview of X-ScaleSolutions**

• **MVAPICH2-DPU**: High-Performance MPI for Accelerating Applications with NVIDIA’s DPU technology

• **X-SCALEAI package**: High-Performance Toolkit for Accelerating DL Applications

• **X-SCALEAI-DPU package**: High-Performance Toolkit for Accelerating DL Applications with intelligent DPU offloading

• Conclusion
X-ScaleSolutions

• Bring innovative and efficient end-to-end solutions, services, support, and training to our customers

• Commercial support and training for the state-of-the-art communication libraries
  • High-Performance and Scalable MVAPICH2 Library and its families (MVAPICH2-X, MVAPICH2-GDR, MVAPICH2-Azure, MVAPICH2-AWS, and OSU INAM)
  • High-Performance Big Data Libraries (RDMA-Hadoop, RDMA-Spark, RDMA-HBase, and RDMA-Memcached)

• Provide commercial support of these Libraries to US federal national labs and international supercomputer centers
X-ScaleSolutions (Cont’d)

• Winner of multiple U.S. DOE SBIR grants to design and develop innovative and value added products

• A Silver ISV member of the OpenPOWER Consortium

• More details on all products in [http://x-scalesolutions.com](http://x-scalesolutions.com)
  • [contactus@x-scalesolutions.com](mailto:contactus@x-scalesolutions.com)
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• Overview of X-ScaleSolutions

• **MVAPICH2-DPU: High-Performance MPI for Accelerating Applications with NVIDIA’s DPU technology**

• **X-ScaleAI package: High-Performance Toolkit for Accelerating DL Applications**

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MVAPICH2-DPU Library

• Based on MVAPICH2 2.3.6
• Current version v2022.02; Next version will be released soon
• Supports all features available with the MVAPICH2 2.3.6 release (http://mvapich.cse.ohio-state.edu)
• Enables offloading non-blocking collectives to DPU
  • Alltoall (MPI_Ialltoall)
  • Allgather (MPI_Iallgather)
  • Broadcast (MPI_Ibcast)
MVAPICH2-DPU Library (Cont’d)

• Significantly increases (up to 100%) overlap of computation with any mix of MPI_Ialltoall, MPI_Iallgather, or MPI_Ibcast non-blocking collectives

• Accelerates scientific applications using any mix of MPI_Ialltoall, MPI_Iallgather, or MPI_Ibcast non-blocking collectives

Available from X-ScaleSolutions, please send a note to contactus@x-scalesolutions.com to get a trial license.
Total Execution Time with osu_ialltoall (32 nodes)

Benefits in Total execution time (Compute + Communication)

32 Nodes, 16 PPN

32 Nodes, 32 PPN
P3DFFT Application Execution Time (32 nodes)

Benefits in application-level execution time

- 32 Nodes, 16 PPN
- 32 Nodes, 32 PPN
Total Execution Time with osu_iallgather (16 nodes)

Benefits in Total execution time (Compute + Communication)
Total Execution Time with osu_Ibcast (16 nodes)

Benefits in Total execution time (Compute + Communication)
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Features of X-ScaleAI Package

• Built on top of MVAPICH2 libraries
• Integrated packaging to support popular DL frameworks
  • TensorFlow, PyTorch, MXNet, etc
• Integrated profiling and introspection support for DL applications across the stacks (DeepIntrospect)
  • Helps users to optimize their DL applications for higher performance and scalability
• Integrated efficient checkpointing restart support
• Targeted for both CPU-based and GPU-based DL training
• One-click deployment and Out-of-the-box optimal performance
• Support for OpenPOWER and x86 platforms
• Support for InfiniBand, RoCE and NVLink Interconnects
System Configuration #1:
• Eight NVIDIA Tesla V100-32GB SXM2 GPUs (per node)
• Two Intel Xeon Gold 6248 "Cascade Lake" CPUs:
  ▪ 20 cores, 2.50–3.90GHz, 27.5MB LLC, 6 memory channels
• 512GB of RAM: DDR4-2933
• 7.68TB NVMe SSD
• Two Mellanox ConnectX-6 InfiniBand HDR 200Gb/s Adapter

Comparison of the performance of training ResNet-50 model on the Imagenet dataset using up to 16 GPUs (2 nodes, 8 GPUs per node) on system configuration #1.
System Configuration #2:

- Four NVIDIA Tesla V100-SXM2 GPUs (per node), connected with NVLink
- Two Intel Xeon Gold 6248 “Cascade Lake” CPUs:
  - 20 cores, 2.50GHz
- 384GB of RAM: DDR4
- 1.6TB Samsung PM1745b NVMe PCIe SSD
- Two Mellanox ConnectX-6 InfiniBand HDR 200Gb/s Adapter

Comparison of the performance of training ResNet-50 model on the Imagenet dataset using up to 16 GPUs (4 nodes, 4 GPUs per node) on system configuration #2
# X-ScaleAI DI GUI Profiler View (Expended)

**Deep Introspect Profiler**

## DEEP INTROSPECT (DI) DASHBOARD:

- **NUMBER OF PROCESSES (NP):** 1024
- **PROCESSES PER NODE (PPN):** 4

**PROMPT:**
```
xscale-ai-run -np 1024 --hostfile .%/file ./xscale-ai/install/miniconda/bin/python ./xscale-ai/install/benchmarks/horovod_benchmarks/pytorch/pytorch_synthetic_benchmark.py --batch-size=64
```

### MPI_Allreduce

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<tr>
<th>TOTAL CALLS</th>
<th>TOTAL TIME (US)</th>
<th>USAGE TAG</th>
<th>MPI OPERATION</th>
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<td>64,843,618</td>
<td>Parameter and Gradients</td>
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#### Latency (us) by Message Size

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<th>Message Size</th>
<th>Count</th>
<th>Latency (us)</th>
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<td>8,212,384</td>
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<td>25,235,712</td>
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#### Count by Message Size

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<tr>
<td>65M</td>
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**X-ScaleSolutions**
Harness 30% higher performance and better scaling on DeepLabv3+ (using TF) with the X-ScaleAI Tool
**X-ScaleAI Use Case #2: Application Benefits (ResNet-50)**

- As a result of tuning the MPI layer, the user can vastly improve application performance

<table>
<thead>
<tr>
<th># GPUs</th>
<th>Images/sec (Expected)*</th>
<th>Images/sec (Obtained Initially)</th>
<th>Images/sec (Obtained Finally)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1024</td>
<td>~370,000</td>
<td>181,020</td>
<td>341,590</td>
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1.9x speedup in ResNet-50 (using PyTorch) throughput, while reducing debugging time for the DL scientist considerably!!
 Efficient Checkpointing for DL Applications

• Based on open-source SCR library from Lawrence Livermore National Laboratories (LLNL)
• Support efficient checkpointing for any DL models and applications using popular DL frameworks
  • PyTorch Distributed Data Parallel Model (DDP)
  • PyTorch Over Horovod
• Example DL Applications:
  • Residual Neural Network (ResNet)
  • Enhanced Deep Residual Networks for Single Image Super-Resolution (EDSR)
Checkpointing performance for ResNet-50

• Similar performance trends observed for the PyTorch over Horovod platform

Training Time (100 Epochs)

Checkpointing Overhead (Naïve vs SCR-Exa)
Checkpointing performance for EDSR

- Similar performance trends observed for the PyTorch over Horovod platform

**Training Time (100 Epochs)**

- **NoCkpt**
- **Naïve Ckpt**
- **SCR Ckpt**

**Checkpointing Overhead (Naïve vs SCR)**

- **Naïve % Overhead**
- **SCR % Overhead**
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X-Scale AI-DPU Package

• Support for distributed CPU-based DL training by offloading different DNN stages to NVIDIA DPUs.
• Intelligent designs to noticeably accelerate DNN training.
• Support for PyTorch/Torchvision and user defined DNN models and datasets.
• User friendly and simple Python API with automatic DNN training function.
• One-click deployment on both x86 and ARM architectures and Out-of-the-box optimal performance
  • Do not need to struggle for many hours
Comparison between DPU offload and CPU only training ResNet-18 model on the CIFAR10 dataset

Comparison between DPU offload and CPU only training ShuffleNet model on the SVHN dataset
Conclusion

• Exponential growth is projected in HPC and AI market in the decades ahead
• HPC software are critical for HPC and DL applications to take full advantages of advanced hardware technologies
  • x86_64/OpenPOWER CPU; NVIDIA/AMD/Intel GPU; NVIDIA DPU, Intel IPU; InfiniBand/High-Speed Ethernet/NVLink networks, etc.
• MVAPICH2-DPU, X-ScaleAI, and X-ScaleAI-DPU from X-ScaleSolutions provide tailored high-performance solutions for your complex HPC and AI applications on your target hardware systems.
• Contact us for a demo and free-trial! (contactus@x-scalesolutions.com)
Thank You!

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http://x-scalesolutions.com/