XL C/C++ and Fortran Compilers
Optimized Exploitation of OpenPOWER CPU & NVIDIA GPU

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Agenda

- **XL Compiler Overview**
  - Compiler suite overview
  - POWER architecture tuning
  - Language Standards support
  - Industry Specifications support

- **Usage Scenarios**
  - Compiling applications with XL C/C++ and XL Fortran
  - Using XL C/C++ as CUDA host compiler
  - Compiling OpenMP 4.5 applications (offloading to GPU)
XL Compiler Overview
XL C/C++ & Fortran Compilers for OpenPOWER

Key Features:

• Highly optimized for POWER processors
• XL C/C++ supports C11, C++11, subset of C++14
• XL Fortran supports Fortran 2003 and majority of Fortran 2008 features
• Support for RHEL 7.3, Ubuntu 16.04 (CUDA8 for GPU offloading)

GPU exploitation with XL C/C++ V13.1.5 & XL Fortran V15.1.5:

• CUDA C/C++: XL C/C++ works as host compiler for POWER
• CUDA Fortran: XL Fortran supports CUDA Fortran extensions
• OpenMP 4.5: subset features to enable GPU offloading

• http://ibm.biz/xlcpp-linux
• http://ibm.biz/xlfortran-linux
XL Compiler Suite Overview

• The XL Compiler Suite
  • Mature C/C++ & Fortran compiler technology on POWER systems
  • Rapidly expanding to support NVIDIA GPU accelerators

• POWER Platform Exploitation
  • Compiler can tune code to run well on both POWER8 & POWER9
  • Full suite of loop transformations, including automatic SIMDization/Vectorization

• Optimized Math libraries
  • Scalar MASS library and vector/SIMD MASSV library tuned for POWER

• IPA (Inter-Procedural Analysis)
  • Full program link time optimization

• PDF (Profile-directed feedback)
  • Tune application performance for typical usage scenarios
Power Architecture and Tuning

- **Ease of POWER 9 exploitation & optimization**
  - Code generated for POWER8 is functionally and performance portable to POWER9
  - Compiler can tune code to run well on both POWER8 & POWER9

- **Default options satisfy most requirements**
  - `-qarch=pwr8` produces code executing on POWER8 & POWER9
  - `-qtune=balanced` balanced tuning for POWER8 & POWER9

- **POWER9 specific options**
  - `-qarch=pwr9` allows compiler to generate POWER9 specific instructions
  - `-qtune=pwr9` tuning for POWER9

- **Compiler & runtime optimizations for POWER9**
  - POWER9 scheduler, auto-SIMDization improvements,
  - IBM Mathematical Acceleration Subsystem (MASS) libraries tuned for POWER9
Optimization infrastructure on the IBM XL compilers

- The IBM XL compilers have a sophisticated and proven optimization infrastructure
  - In development at IBM for over 30 years
  - Widely used on production environments both inside and outside IBM
  - Large focus on runtime performance and platform exploitation

- **Noopt, -O0**
  - Quick local optimizations
  - Keep the semantics of a program

- **-O2**
  - Optimizations for the best combination of compile speed and runtime performance
  - Keep the semantics of a program

- **-O3**
  - Equivalent to -O3 -qhot=level=0
  - Focus on runtime performance at the expense of compilation time: loop transformations, dataflow analysis

- **-Ofast**
  - Equivalent to -O3 -qhot
  - Perform aggressive loop transformations and dataflow analysis at the expense of compilation time

- **-qipa**
  - Aggressive optimization: whole program optimization; aggressive dataflow analysis and loop transformations

- **-qpdf**
  - Whole program optimization; profile information feeds runtime performance of application into compiler for further
Language Standard Support

Starting from IBM XL C/C++ for Linux, V13.1.3 the compiler is:
- C89, C99, C11 and C++98, C++03, C++11 compliant
- Partial support for C++14 features:
  - Polymorphic lambda expressions
  - Variable templates

XL Fortran, V15.1.5 supports the following ANSI standards:
- Full support for Fortran 77, Fortran 90, Fortran 95, Fortran 2003
- Partial support for the ISO Fortran 2008 language standard
  - No coarrays support, compliance status @ [http://ibm.biz/Fortran2008Status](http://ibm.biz/Fortran2008Status)
  - Partial support for Technical Specification for further interoperability with C
    - Latest status @ [http://ibm.biz/FortranTS29113Status](http://ibm.biz/FortranTS29113Status)
Industry Specifications

- IBM XL C/C++ and Fortran support for OpenMP
  - Full support for the OpenMP API Version 3.1
  - Partial support for the latest OpenMP 4.5 specification

- IEEE 754-2008 IEEE Standard for Floating-Point Arithmetic

- Subset of GNU C and C++ language extensions

- More Information:
  - [http://ibm.biz/xlcpp-linux](http://ibm.biz/xlcpp-linux)
  - [http://ibm.biz/xlfortran-linux](http://ibm.biz/xlfortran-linux)
Usage Scenarios
Compiling Applications with XLC and XLF

• **Set up the path for IBM XL compilers**
  
  export PATH=/opt/ibm/xlC/13.1.5/bin:/opt/ibm/xlf/15.1.5/bin:$PATH

• **Check the compiler release and version**
  
  xlc –qversion
  xlC -qversion
  xlf –qversion

• **Compile an application**
  
  xlc for C (add –qlanglvl=stdc99 or stdc11 to enable C99-C11 )
  xlC for C++ (add –qlanglvl=c++11 to enable C++11)
  xlf, xlf90, xlf95, xlf2003, xlf2008 for Fortran

• **Specify typical compile options**
  
  -O3 or –Ofast for floating point computation intensive application
  -qnostrict to allow optimizer to reassociate floating point computations, use FMA, …
  -qarch=pwr8 to use POWER8 instruction set
Compiling OpenMP applications with XLC and XLF

- Enable GPU offloading for OpenMP applications
  - `xlc_r -O3 -qsmp=omp -qoffload saxpy.cpp -o saxpy`
  - `xlf95_r -O3 -qsmp=omp -qoffload saxpy.f -o saxpy`
  - Help: use `-qhelp` for list of options available

- Verify OpenMP 4.5 target regions are executed on the NVIDIA GPU

  $ xlf95_r -qsmp=omp -qoffload saxpy.f -o saxpy
  ** main === End of Compilation 1 ===
  1501-510 Compilation successful for file saxpy.f.

  $ cuda-memcheck saxpy
  ============= CUDA-MEMCHECK
  SAXPY time: 0.1099999994 seconds
  x( 1 )= 2.0000000000 y( 1 )= 2.0000000000
  x( 4 )= 2.0000000000 y( 4 )= 2.0000000000
  Test Passed
  ============= ERROR SUMMARY: 0 errors
Using XL C/C++ as host compiler for CUDA C/C++

- NVCC can use GCC or XLC as host compiler for POWER CPU
  - NVCC is NVIDIA CUDA C++ Compiler from NVIDIA CUDA Toolkit
  - NVCC partitions C/C++ source code into CPU and GPU portions

- XL C/C++ compiler can be used as host compiler for NVCC
  - Can be used with NVCC version 7.5 & 8.0
  - Fully leverage advanced compiler optimization for POWER CPU

- Detailed instructions for using XLC:
  - Page 23 of this presentation, or

- Invocation example:
  - nvcc -ccbin xlC -m64 -Xcompiler -O3 -Xcompiler -q64 -Xcompiler -qsmp=omp -gencode arch=compute_20,code=sm_20 -o cudaOpenMP.o -c cudaOpenMP.cu
  - nvcc -ccbin xlC -m64 -Xcompiler -O3 -Xcompiler -q64 -o cudaOpenMP cudaOpenMP.o -lxlSmp
Additional Information

- XL C/C++ home page

- XL Fortran home page

- XL Compiler Community
  - http://ibm.biz/xlcpp-linux-ce

- Code optimization with the IBM XL compilers on Power architectures

- Performance Optimization and Tuning Techniques for IBM Power Systems Processors Including IBM POWER8

- Implementing an IBM High-Performance Computing Solution on IBM POWER8
Thank You
Questions
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