Intel® Xeon Phi™ Product Family

The GNU* Project Debugger (GDB)

Software and Services Group
Intel Corporation

Agenda

- Overview
- Intel® Xeon Phi™ Coprocessor Features
- Native / Manycore hosted Debugging
- Remote Debugging and Offloaded Execution
- Debugging Data Races
- Shared Virtual Memory
- Eclipse Integration
- Summary

Overview

Linux*: Intel debug solution based on GNU* GDB 7.5

- Capabilities are upstreamed to GNU* community
- C/C++ support, improved Fortran support
- Parallel Debug Extensions (PDBX)
- BTrace: crash-resistant back-trace
- Pointer Checker: assist in finding pointer issues
- Intel® Transactional Synchronization Extensions

Intel® Debugger (Intel® IDB) is deprecated

- Last version remains 13.0

Overview: Intel® Xeon Phi™

GDB* supports Intel® Xeon Phi™ Coprocessors

- Available via Intel® MPSS
  - Intel® Manycore Platform Software Stack (Intel® MPSS): http://software.intel.com/en-us/articles/intel-manycore-platform-software-stack-mpss
  - Via product suite e.g., Intel® Composer XE

GDB* on Intel® Xeon Phi™ Coprocessors

- Native and cross/remote debugger versions
- C/C++ support, improved Fortran support
- Parallel Debug Extensions (PDBX)

Optimization Notice

GDB* in Intel MPSS

Coprocessor

- Debug server and host debugger (PDBX, etc.)
  - `/usr/linux-k1om-4.7/linux-k1om/usr/bin/gdbserver`
  - `/usr/linux-k1om-4.7/bin/x86_64-k1om-linux-gdb`
- Native debugger (no PDBX)
  - `/usr/linux-k1om-4.7/linux-k1om/usr/bin/gdb`

Host debugger (PDBX, etc.)

- `/opt/intel/mic/bin/gdb`

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Intel® Xeon Phi™ Coprocessor Architecture Features

List all new vector and mask registers

```
(gdb) info registers zmm
K0     0x0      0
       ⋮
Zmm31  {v16_float = {0x0 <repeats 16 times>},
        v8_double = {0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0},
        v64_int8 = {0x0 <repeats 64 times>},
        v32_int16 = {0x0 <repeats 32 times>},
        v16_int32 = {0x0 <repeats 16 times>},
        v8_int64 = {0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0},
        v4_uint128 = {0x0, 0x0, 0x0, 0x0}}
```

Disassemble instructions

```
(gdb) disassemble $pc, +10
Dump of assembler code from 0x11 to 0x24:
0x0000000000000011 <foobar+17>:
      vpackstorelps %zmm0,-0x10(%rbp){%k1}
0x0000000000000018 <foobar+24>:
      vbroadcastss -0x10(%rbp),%zmm0
```

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Native / Manycore hosted Debugging

Run GDB* on the Intel® Xeon Phi™ Coprocessor

```
ssh -t mic0 /usr/bin/gdb
```

To attach to a running application via the process-id

```
(gdb) shell pidof my_application
42
(gdb) attach 42
```

To run an application directly from GDB*

```
(gdb) file /target/path/to/application
(gdb) start
```

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Remote Debugging

Run GDB* on your localhost

```
/usr/linux-k1om-4.7/bin/x86_64-k1om-linux-gdb
```

Start gdbserver on the coprocessor

- To remote debug using |ssh

```
(gdb) target extended-remote | ssh -T mic0 gdbserver -multi
IP:port
```

- To remote debug using stdio

```
(gdb) target extended-remote | ssh -T mic0 gdbserver -multi -
```

Attach to a running application via process ID (pid)

```
(gdb) file /local/path/to/application
(gdb) attach <remote-pid>
```

Run an application directly

```
(gdb) file /local/path/to/application
(gdb) set remote exec-file /target/path/to/application
```

Offloaded Execution

Debugging into an offloaded code section on the host does not "switch" to a debugger on the target

- No debug synchronization (host / coprocessor)
- GUI integration will provide this "glue" logic; see "Upcoming Features" (Eclipse*)

Debugging offloaded code via command line

1. Wait within the offloaded code section

```
volatile int loop = 1;
do {
  volatile int a = 1;
} while (loop);
```

2. Attach to offload process on coprocessor via PID

Note: cross-compiling the entire application and debugging the previously offloaded section natively might be easier.

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Debugging Data Races: Example

Given: global variables

a=1

b=2

Given: two threads

T1: x = a + b

T2: b = 42

Value of x depends on execution order:

If T1 runs before T2 → x = 3

If T2 runs before T1 → x = 43

Data race e.g., “read-write”:

T2’s update was not visible to T1’s calculation

Debugging Data Races: Symptoms

Debug data race symptoms

- Corrupted results (lost updates, large run-to-run variations in results, etc.)
- Corrupted data structures (crash)

Note: different levels of synchronization possible

- Thread-level ordering (global synchronization)
- Instruction level ordering / visibility (e.g., atomics)
  - Race-free but not necessarily run-to-run reprod. results
- No synchronization (data races might be acceptable)

Debugging Data Races: Detection

How to detect data races?

- Compile with "-debug parallel" (icc/icpc/ifort only)
- Coprocessor: debug server with corresponding host GDB*
- Host: enhanced GDB* (`/opt/intel/mic/bin/gdb`)

Debugger breaks when race has been detected:

```
(gdb) pdbx enable
(gdb) c
data race detected
1: write shared, 4 bytes from foo.c:36
3: read shared, 4 bytes from foo.c:40

Breakpoint -11, 0x401515 in L_test_..._21 () at
foo.c:36
*var = 42; /* bp.write */
```

Stop in the context of the access that triggers a race condition

Debugging Data Races: Filter Sets

Fine-tune detection and analysis via filter sets

- Add filter to selected filter set

```
(gdb) pdbx filter line foo.c:36
(gdb) pdbx filter code 0x40518..0x40524
(gdb) pdbx filter var shared
(gdb) pdbx filter data 0x60f48..0x60f50
(gdb) pdbx filter reads # read accesses
```

- Ignore events specified by filters (default behavior)

```
(gdb) pdbx fset suppress
```

- Ignore events not specified by filters

```
(gdb) pdbx fset focus
```

- Get debug command help (pdbx)

```
(gdb) help pdbx
```

Use cases

- Focused debugging e.g., debug a single symptom
- Limit overhead and control false positives

Optimization Notice

Debugging Data Races: Hints

Optimized code (symptom)

```
 (gdb) run
 data race detected
 1: write question, 4 bytes from foo.c:36
 3: read question, 4 bytes from foo.c:40

 Breakpoint -11, 0x401515 in foo () at foo.c:36
36 *answer = 42;
 (gdb)
```

Reported variable may appear to be wrong

- Remember: data races are reported on memory objects
- If symbol name cannot be resolved: only address is printed

Recommendation

- Unoptimized code (O0): avoids to miss finding data races (due to removed / optimized away temporaries, etc.)

Debugging Data Races: Hints (cont.)

Reported data races appear to be false positives e.g.,

- Distinct parallel sections (same stack frame) using the same variable can result in false positives
- Solution: enable/setup instrumentation (libiomp5)

Recommendation

- Set additional environment variables:
  INTEL_LIBITTNOTIFY64=""
  INTEL_ITTNOTIFY_GROUPS=sync

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Shared Virtual Memory

Programming model

1. Expose shared resources
   - Allocate and access shared virtual memory (SVM)
   - Address / pointer is valid on host and coprocessor
2. Offload computation
   - Implicit / sparse data transfers (byte or page granularity)
   - Seamlessly share complex data structures

How it works

- MMU page protection faults used to synchronize memory

Use it via

- MYO C API (“Mine Yours Ours”)
- Intel® Cilk Plus™ (C and C++)

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Shared Virtual Memory and GDB*

Enhanced GDB* distinguishes between invalid page faults and page faults used for Shared Virtual Memory.

Example: GDB* without SVM-awareness

- Use of SVM triggers segmentation violation

```
(gdb) run
Program received signal SIGSEGV,
Segmentation fault.
0x0000000000401c90 in foobar()
```

Example: enhanced GDB* allows transparent debugging

- Awareness for segmentation violations used by SVM

```
(gdb) run
Program exited normally
```

- Display shared variables similar to regular variables

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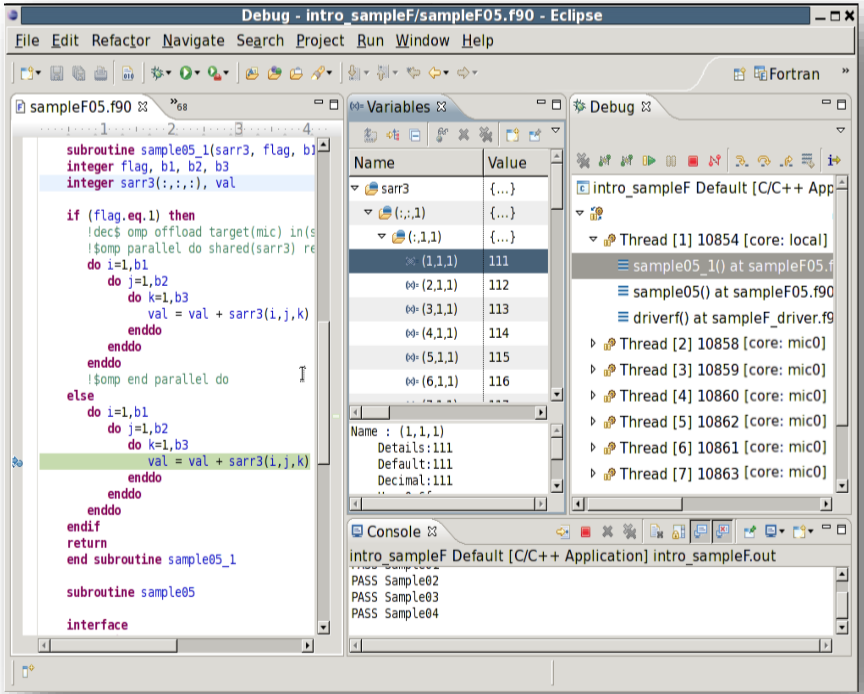
Eclipse Integration

Eclipse* IDE integration

- Seamless debugging of host and coprocessor
- Simultaneous view of host and coprocessor threads
- Supports offload language extensions (auto-attach to offload process)
- Supports multiple coprocessor cards
- Supports C/C++ and Fortran



Simultaneous and seamless thread debugging.

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Summary

Support for multiple debug models

- Native / remote target debugging
- Upcoming GUI integration

Aware of extended programming models

- Explicit offload model and SVM model

GDB* for Intel® Xeon Phi™ Coprocessor

- http://software.intel.com/en-us/articles/intel-manycore-platform-software-stack-mpss

Debug your offloaded / native code with GDB*

Questions?

Thank You

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