OAK RIDGE National Laboratory

Clacc 2019: An Update on OpenACC Support for Clang and LLVM

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Clacc Overview

Clacc Background

OpenACC

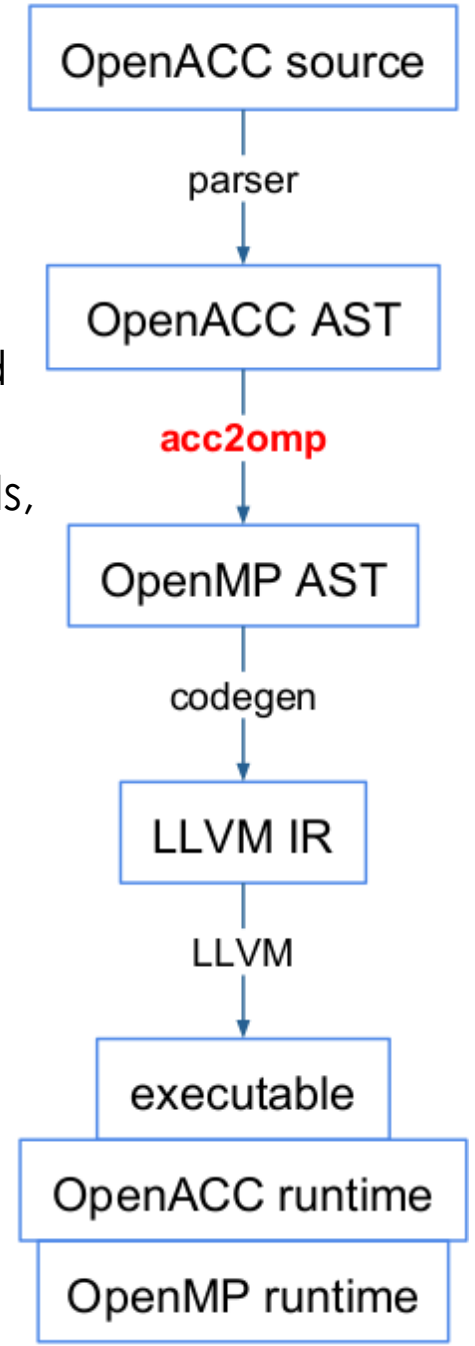
- Launched 2010 as portable directive-based programming model in C, C++, Fortran for heterogeneous accelerators
- Best known for NVIDIA GPU; implementations have targeted AMD GCN, multicore CPU, Intel Xeon Phi, FPGA
- Compared to OpenMP
  - Descriptive vs. Prescriptive
  - Many features ported to OpenMP
  - Specification less complex
- OpenACC 2.7 released in Nov, 2018

Clacc

- US Exascale Computing Project (ECP)
- Goal: Open-source, production-quality, standard-conforming OpenACC compiler support for Clang and LLVM
- Why?
  - Needed for HPC app development and OpenACC adoption and evolution
  - GCC is only open-source, production-quality compiler supporting OpenACC
- Design: Translate OpenACC to OpenMP to build on OpenMP support in Clang

Clacc Current Design

- Need AST transformation
  - OpenACC AST for source-level tools: pretty printers, analyzers, lint tools, and debugger and editor extensions, etc.
  - OpenMP AST for source-to-source: reuse OpenMP implementation and tools, automatically port apps, etc.
- Problem
  - Clang AST is immutable by design
- Solution
  - Add hidden OpenMP subtree for each OpenACC subtree
  - Using Clang's TreeTransform facility
  - TreeTransform nicely encapsulates reuse of Sema implementations
  - TreeTransform uses CRTP to be extensible



Clacc Roadmap

2019 and earlier

- Focus on C
- Focus on behavioral correctness
  - Prescriptive OpenACC interpretation
  - Many-to-one mapping to OpenMP
- Propose fixes to OpenACC spec
- Upstreaming mutually beneficial improvements to Clang and LLVM

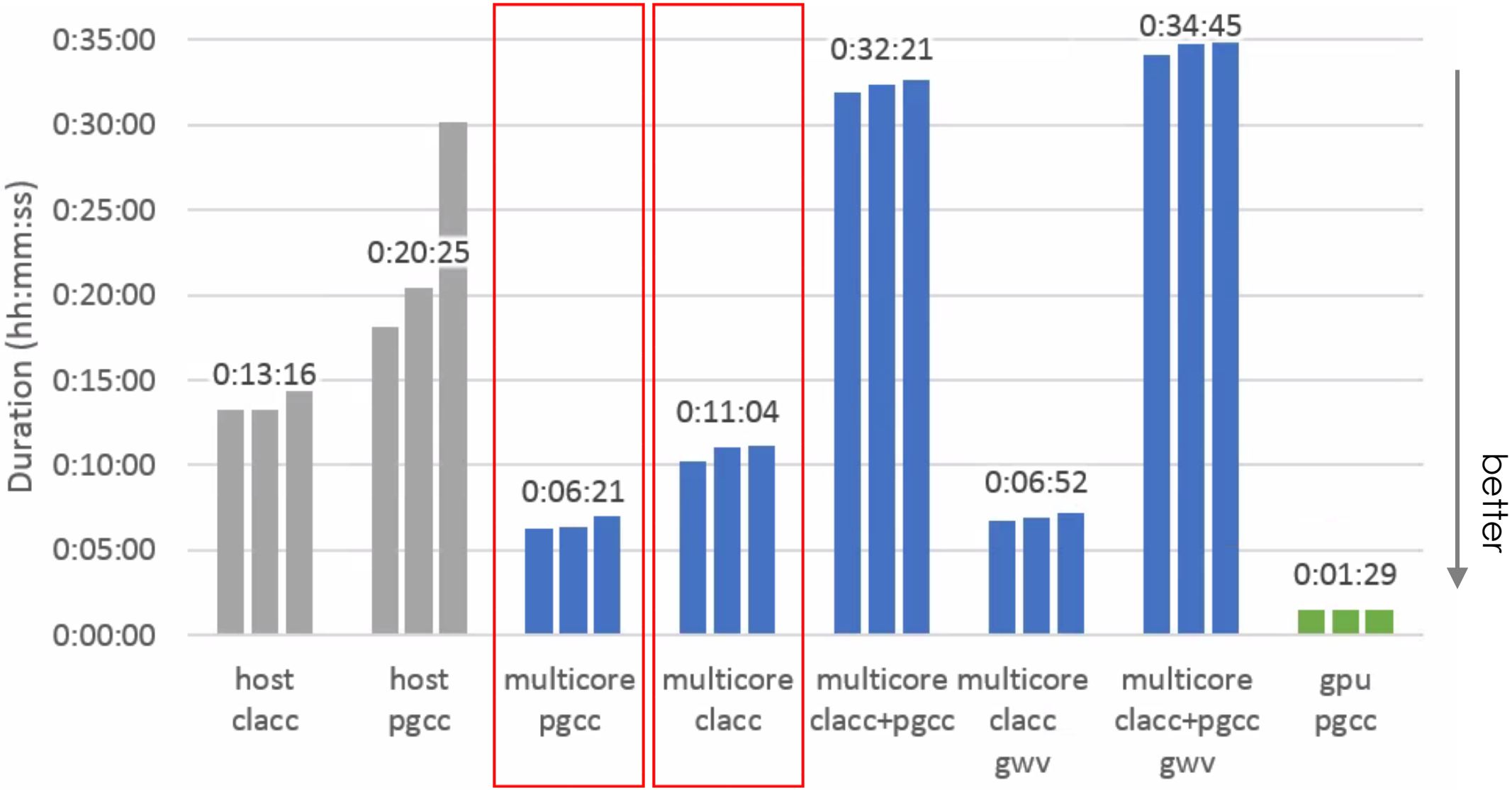
2020 and later

- Extend to C++
- Focus on performance
  - Descriptive OpenACC interpretation
  - Analyses for best mapping to OpenMP
  - Investigate advanced LLVM analyses (e.g., autotuning, polly, LLVM IR extensions)
- Upstreaming OpenACC support

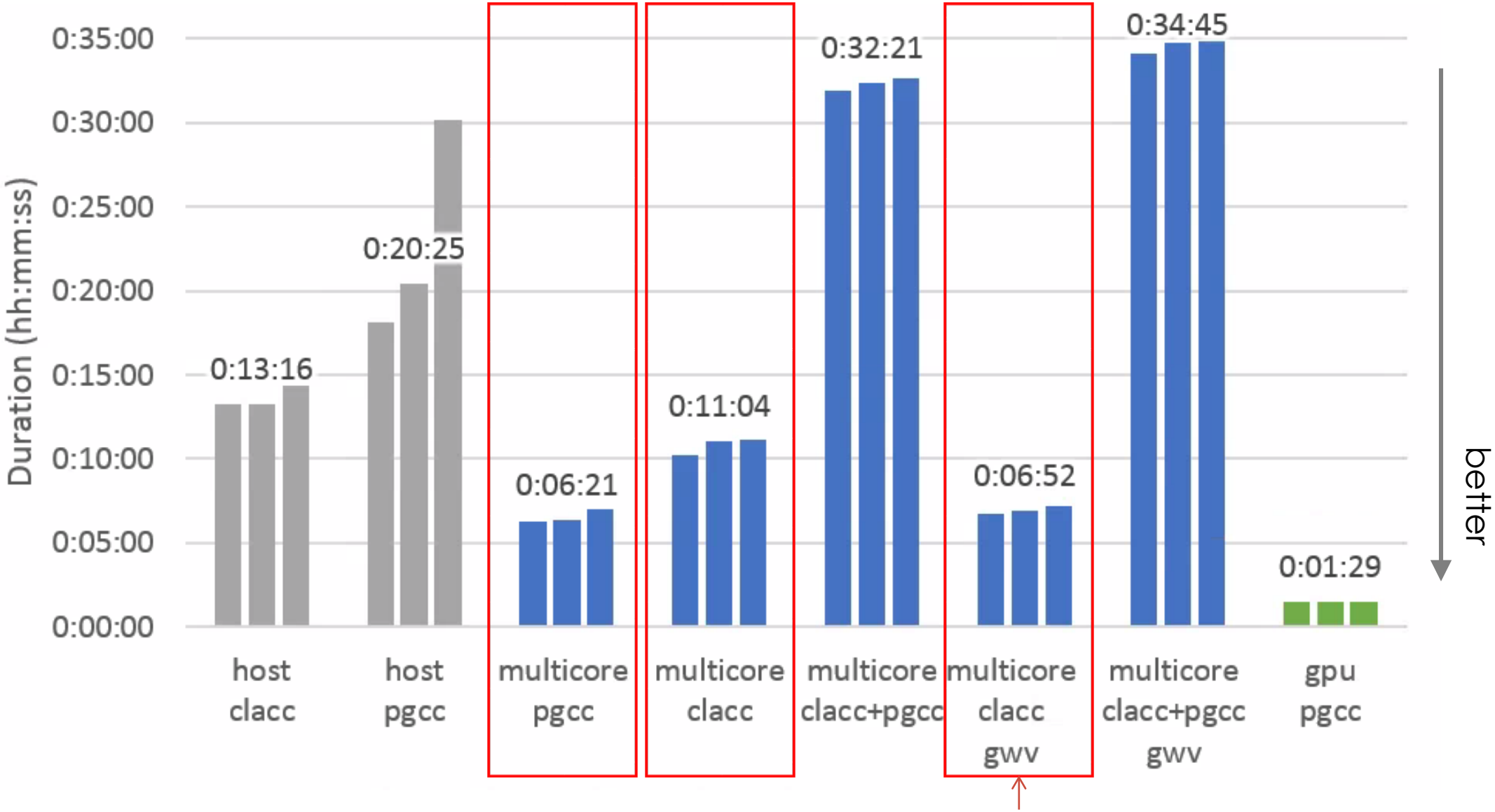
Early Performance Results

Clacc: Translating OpenACC to OpenMP in Clang, Joel E. Denny, Seyong Lee, and Jeffrey S. Vetter, 2018 IEEE/ACM 5th Workshop on the LLVM Compiler Infrastructure in HPC (LLVM-HPC), Dallas, TX, USA, (2018).

SPEC ACCEL 303.ostencil



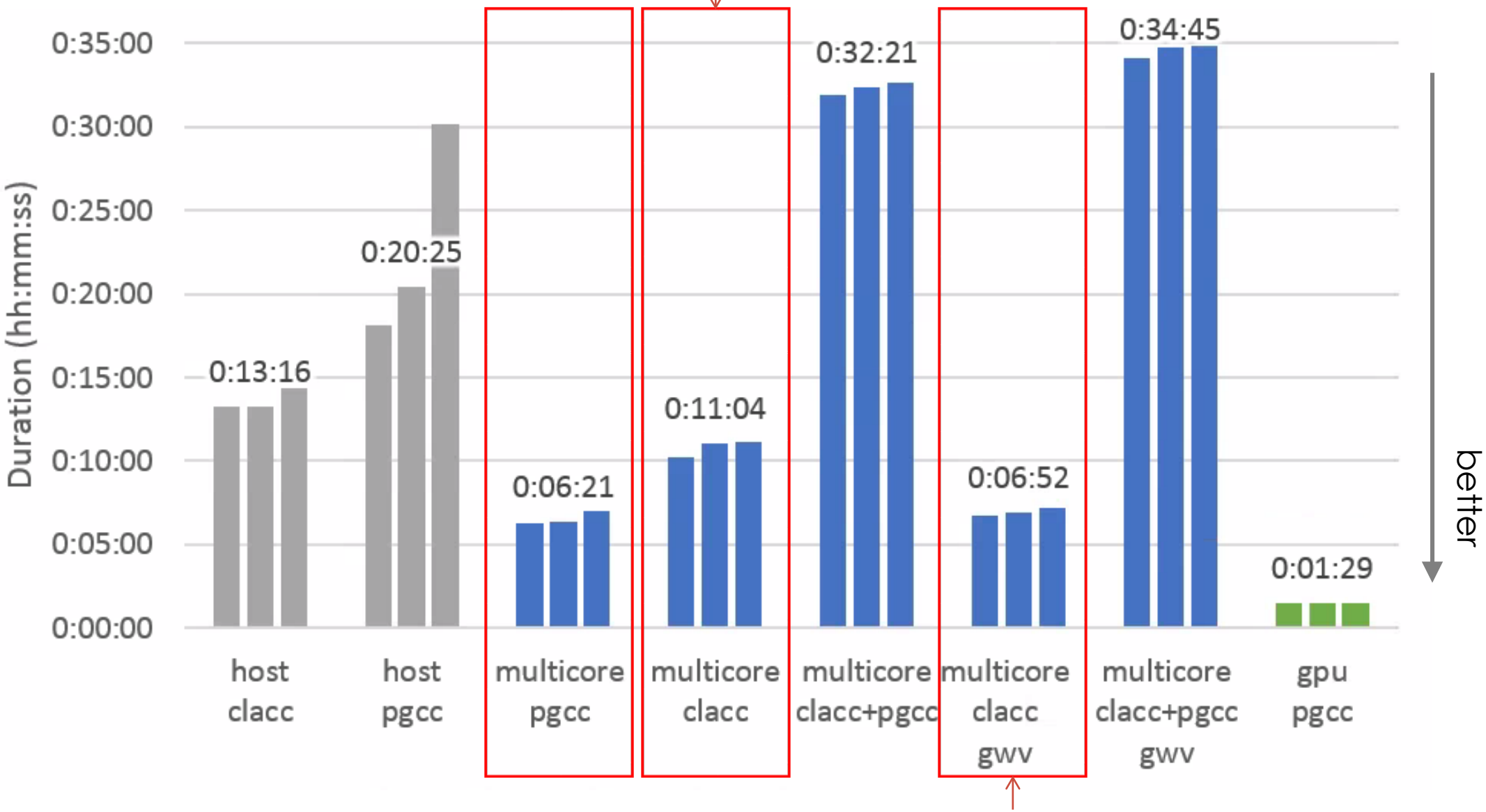
SPEC ACCEL 303.ostencil



Manually added *prescriptive* gang/worker/vector
(like OpenMP distribute/parallel for/simd)

SPEC ACCEL 303.ostencil

Needs *descriptive* interpretation



Manually added *prescriptive* gang/worker/vector
(like OpenMP distribute/parallel for/simd)

Upstream Contributions

- Mutually beneficial contributions
- Not OpenACC-specific yet
- Big thanks to reviewers and others in the LLVM community!

Clang and OpenMP Improvements

- OpenMP Parse and Sema fixes
- Clang -ast-print fixes
  - Affects Clacc in source-to-source mode
- Attribute handling fixes
- Debian/Ubuntu nvidia-cuda-toolkit support fixes
  - Affects OpenMP/OpenACC offloading support
- Add libraries to Clang-dedicated directories
  - Avoids incorrect linking of libomp*.so
  - In progress

Testing Infrastructure Improvements

- clang -cc1 -verify=<prefixes>
  - like FileCheck -check-prefixes=<prefixes>
  - // expected-error {{message}}
  - // your-prefix-error {{message}}
- lit -vv shows line number for failed RUN command
  - Some lit tests have hundreds of RUN commands
- FileCheck CHECK-DAG behavior cleanup
  - Most notably, matches are now non-overlapping
  - More intuitive and less error-prone
  - Enables checking unordered, non-unique strings (e.g., from parallel program)

FileCheck Debugging

- FileCheck -v and -vv
  - Traces matches
- FileCheck -color
  - Forces color output through lit/ninja
- FileCheck -dump-input=always | fail | never
  - Dumps input annotated with diagnostics
- FILECHECK_OPTS environment var
  - Passes command-line options through lit/ninja
  - FILECHECK_OPTS='-vv –color –dump-input=fail' ninja check-clang-openmp

FileCheck normal diagnostic

Input

```
1: store i64 %0, i64* %1
2: store i64 %2, i64* %3
3: store i64 %4, i64* %5
4: store i64 %6, i64* %7
5: store i32 %8, i32* %9
6: store i64 %10, i64* %11
7: ret i32 %8
```

Checks

```
1: CHECK: store i64 %{{[0-9]+}}, i64* %{{[0-9]+}}
2: CHECK: store i64 %{{[0-9]+}}, i64* %{{[0-9]+}}
3: CHECK: store i64 %{{[0-9]+}}, i64* %{{[0-9]+}}
4: CHECK: store i32 %{{[0-9]+}}, i32* %{{[0-9]+}}
5: CHECK: store i64 %{{[0-9]+}}, i64* %{{[0-9]+}}
6: CHECK: store i64 %{{[0-9]+}}, i64* %{{[0-9]+}}
```

Error at CHECK on line 6?

```
check:6:8: error: CHECK: expected string not found in input
CHECK: store i64 %{{[0-9]+}}, i64* %{{[0-9]+}}
       ^

<stdin>:7:1: note: scanning from here
ret i32 %8
^
```

FileCheck -v -dump-input=fail

Input

```
1: store i64 %0, i64* %1
2: store i64 %2, i64* %3
3: store i64 %4, i64* %5
4: store i64 %6, i64* %7
5: store i32 %8, i32* %9
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4: CHECK: store i32 %{{[0-9]+}}, i32* %{{[0-9]+}}
5: CHECK: store i64 %{{[0-9]+}}, i64* %{{[0-9]+}}
6: CHECK: store i64 %{{[0-9]+}}, i64* %{{[0-9]+}}
```

```
Full input was:
<<<<<<
          1: store i64 %0, i64* %1
check:1      ^~~~~~~~~~~~~~~~~~~~
          2: store i64 %2, i64* %3
check:2      ^~~~~~~~~~~~~~~~~~~~
          3: store i64 %4, i64* %5
check:3      ^~~~~~~~~~~~~~~~~~~~
          4: store i64 %6, i64* %7
          5: store i32 %8, i32* %9
check:4      ^~~~~~~~~~~~~~~~~~~~
          6: store i64 %10, i64* %11
check:5      ^~~~~~~~~~~~~~~~~~~~~~
          7: ret i32 %8
check:6      X~~~~~~~~~ error: no match found
>>>>>>
```

FileCheck -v -dump-input=fail

Input

```
1: store i64 %0, i64* %1
2: store i64 %2, i64* %3
3: store i64 %4, i64* %5
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5: store i32 %8, i32* %9
6: store i64 %10, i64* %11
7: ret i32 %8
```

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4: CHECK: store i32 %{{[0-9]+}}, i32* %{{[0-9]+}}
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check:5      ^~~~~~~~~~~~~~~~~~~~~~
          7: ret i32 %8
check:6      X~~~~~~~~~ error: no match found
>>>>>>
```

Ah! Problem actually occurred earlier: Line 4 never matched!

FileCheck -v -dump-input=fail

Input

```
1: store i64 %0, i64* %1
2: store i64 %2, i64* %3
3: store i64 %4, i64* %5
4: store i64 %6, i64* %7
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```

Checks

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5: CHECK: store i64 %{{[0-9]+}}, i64* %{{[0-9]+}}
6: CHECK: store i64 %{{[0-9]+}}, i64* %{{[0-9]+}}
```

reversed directives

```
Full input was:
<<<<<<
          1: store i64 %0, i64* %1
check:1      ^~~~~~~~~~~~~~~~~~~~
          2: store i64 %2, i64* %3
check:2      ^~~~~~~~~~~~~~~~~~~~
          3: store i64 %4, i64* %5
check:3      ^~~~~~~~~~~~~~~~~~~~
          4: store i64 %6, i64* %7
          5: store i32 %8, i32* %9
check:4      ^~~~~~~~~~~~~~~~~~~~
          6: store i64 %10, i64* %11
check:5      ^~~~~~~~~~~~~~~~~~~~~~
          7: ret i32 %8
check:6      X~~~~~~~~~ error: no match found
>>>>>>
```

Ah! Problem actually occurred earlier: Line 4 never matched!

Clacc Takeaways

- Overview
  - Objective: Production-quality OpenACC compiler support for Clang and LLVM
  - Design: Translate OpenACC to OpenMP to build on existing OpenMP support in Clang
- Roadmap
  - <= 2019: C, correctness, upstream mutually beneficial improvements
  - >= 2020: C++, performance, upstream OpenACC support
- Join Us
  - Future Technologies Group, Oak Ridge National Laboratory
  - Hiring interns, postdocs, research and technical staff
  - External collaborators welcome

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