

背景

随着 Dennard 缩放法的结束和处理器性能提升的放缓，以及对于开发非基于 trace 的仿真环境的根本需求，本文介绍了一种名为 gem5-SALAM 的系统架构，用于 LLVM-based 加速器建模和模拟。该架构克服了传统基于 trace 的 pre-register-transfer level (RTL) 模拟器的局限性，提供了真正的“执行-执行”LLVM 模型。它能够可扩展地建模多个动态交互的加速器，并支持全系统仿真。该架构具有与 gem5 系统框架兼容的通用和模块化的通信接口和内存层次。该架构还提供了循环级性能分析和完整系统设计空间探索功能。

研究问题

研究问题集中在如何克服现有基于追踪的寄存器传输级（RTL）模拟器的限制，以实现更真实、更可扩展的模拟。gem5-SALAM能够模拟多个动态交互的加速器，并提供完整系统仿真支持。

采用方法

采用的方法包括创建一个基于LLVM的模型，它能够准确地模拟数据路径结构、面积和静态泄露功率。此外，它还实现了基于动态LLVM的运行时执行引擎，允许对动态功率和时序进行周期精确的建模。该系统还具有独立调谐数据路径和存储器基础设施的能力，以及与gem5的灵活系统集成，以支持复杂的加速器间通信和同步。

实验结果

接下来是实验复现部分，本人首先在docker中进行编译测试

将本地 clone 下来的仓库拷贝到 docker 中

```
~
> docker run -itd --name lab --platform linux/amd64 ubuntu:20.04

> docker ps
CONTAINER ID   IMAGE          COMMAND                  CREATED        STATUS        PORTS        NAMES
7e6b2a3a4a52   ubuntu:20.04   "/bin/bash"             4 minutes ago Up 4 minutes   lab

> docker cp gem5-SALAM 7e:/root/
Successfully copied 306MB to 7e:/root/
```

```
mdZNNbC12ZWNlcmUeSBldWx0aXZlcmluI - base64 -d > /etc/apt/sources.list
root@7e6b2a3a4a52:~# apt update
Get:1 http://archive.ubuntu.com/ubuntu focal InRelease [265 kB]
Get:2 http://security.ubuntu.com/ubuntu focal-security InRelease [114 kB]
Get:3 http://archive.ubuntu.com/ubuntu focal-updates InRelease [114 kB]
Get:4 http://archive.ubuntu.com/ubuntu focal-backports InRelease [108 kB]
Get:5 http://archive.ubuntu.com/ubuntu focal/universe amd64 Packages [11.3 MB]
Get:6 http://security.ubuntu.com/ubuntu focal-security/universe amd64 Packages [1149 kB]
Get:7 http://archive.ubuntu.com/ubuntu focal/main amd64 Packages [1275 kB]
Get:8 http://archive.ubuntu.com/ubuntu focal/multiverse amd64 Packages [177 kB]
Get:9 http://archive.ubuntu.com/ubuntu focal/restricted amd64 Packages [33.4 kB]
Get:10 http://archive.ubuntu.com/ubuntu focal-updates/multiverse amd64 Packages [32.0 kB]
Get:11 http://archive.ubuntu.com/ubuntu focal-updates/universe amd64 Packages [1444 kB]
Get:12 http://archive.ubuntu.com/ubuntu focal-updates/main amd64 Packages [3761 kB]
Get:13 http://security.ubuntu.com/ubuntu focal-security/main amd64 Packages [3283 kB]
Get:14 http://archive.ubuntu.com/ubuntu focal-updates/restricted amd64 Packages [3279 kB]
Get:15 http://security.ubuntu.com/ubuntu focal-security/multiverse amd64 Packages [29.3 kB]
Get:16 http://archive.ubuntu.com/ubuntu focal-backports/universe amd64 Packages [28.6 kB]
Get:17 http://security.ubuntu.com/ubuntu focal-security/restricted amd64 Packages [3130 kB]
Get:18 http://archive.ubuntu.com/ubuntu focal-backports/main amd64 Packages [55.2 kB]
Fetched 29.6 MB in 13s (2286 kB/s)
Reading package lists... Done
Building dependency tree
Reading state information... Done
All packages are up to date.
root@7e6b2a3a4a52:~# apt install
```

apt 安装编译所需要的工具

```
apt install build-essential git m4 scons zlib1g zlib1g-dev libprotobuf-dev protobuf
```

再安装 LLVM / Clang

```
apt install llvm-12 llvm-12-tools clang-12 -y
```

安装完之后，运行文件 `./docs/update-alternatives.sh`

```
#!/bin/sh
```

```
update-alternatives --install "/usr/bin/clang" "clang" "/usr/bin/clang-12" 100 \  
    --slave "/usr/bin/bugpoint" "bugpoint"  
    --slave "/usr/bin/clang++" "clang++"  
    --slave "/usr/bin/llc" "llc"  
    --slave "/usr/bin/lli" "lli"  
    --slave "/usr/bin/llvm-ar" "llvm-ar"  
    --slave "/usr/bin/llvm-as" "llvm-as"  
    --slave "/usr/bin/llvm-bcanalyzer" "llvm-bcanalyzer"  
    --slave "/usr/bin/llvm-config" "llvm-config"  
    --slave "/usr/bin/llvm-cov" "llvm-cov"  
    --slave "/usr/bin/llvm-c-test" "llvm-c-test"  
    --slave "/usr/bin/llvm-cxxdump" "llvm-cxxdump"  
    --slave "/usr/bin/llvm-diff" "llvm-diff"  
    --slave "/usr/bin/llvm-dis" "llvm-dis"  
    --slave "/usr/bin/llvm-dwarfdump" "llvm-dwarfdump"  
    --slave "/usr/bin/llvm-dwp" "llvm-dwp"  
    --slave "/usr/bin/llvm-extract" "llvm-extract"  
    --slave "/usr/bin/llvm-lib" "llvm-lib"  
    --slave "/usr/bin/llvm-link" "llvm-link"  
    --slave "/usr/bin/llvm-lto" "llvm-lto"  
    --slave "/usr/bin/llvm-mc" "llvm-mc"  
    --slave "/usr/bin/llvm-nm" "llvm-nm"  
    --slave "/usr/bin/llvm-objdump" "llvm-objdump"  
    --slave "/usr/bin/llvm-profdata" "llvm-profdata"  
    --slave "/usr/bin/llvm-ranlib" "llvm-ranlib"  
    --slave "/usr/bin/llvm-readobj" "llvm-readobj"  
    --slave "/usr/bin/llvm-rtdyld" "llvm-rtdyld"  
    --slave "/usr/bin/llvm-size" "llvm-size"  
    --slave "/usr/bin/llvm-split" "llvm-split"  
    --slave "/usr/bin/llvm-stress" "llvm-stress"  
    --slave "/usr/bin/llvm-symbolizer" "llvm-symbolizer"  
    --slave "/usr/bin/llvm-tblgen" "llvm-tblgen"  
    --slave "/usr/bin/obj2yaml" "obj2yaml"  
    --slave "/usr/bin/opt" "opt"  
    --slave "/usr/bin/verify-uselistorder" "verify-uselistorder"  
    --slave "/usr/bin/yaml2obj" "yaml2obj"
```

```
$ ./docs/update-alternatives.sh
```

```
update-alternatives: using /usr/bin/clang-12 to provide /usr/bin/clang (clang) in auto |
```

构建 gem5-SALAM 时，可以创建多种不同的二进制类型。就像在 gem5 中一样，选项是 debug、opt、fast、prof 和 perf

以下是用于构建 opt 或 debug 二进制文件的 bash 命令

```
scons build/ARM/gem5.opt -j`nproc`
```

```
scons build/ARM/gem5.debug -j`nproc`
```

一开始会出现这个报错，但是发现把 .git 目录移走就好了

```
root@7e6b2a3a4a52:~/gem5-SALAM# scons build/ARM/gem5.opt -j`nproc`
scons: Reading SConscript files ...
```

You're missing the gem5 style or commit message hook. These hooks help to ensure that your code follows gem5's style rules on git commit.

This script will now install the hook in your .git/hooks/ directory.

Press enter to continue, or ctrl-c to abort: FileNotFoundError: [Errno 2] No such file

File `"/root/gem5-SALAM/SConstruct"`, line 145:

```
main = Environment(tools=[
```

File `"/usr/lib/scons/SCons/Environment.py"`, line 990:

```
    apply_tools(self, tools, toolpath)
```

File `"/usr/lib/scons/SCons/Environment.py"`, line 102:

```
    env.Tool(tool)
```

File `"/usr/lib/scons/SCons/Environment.py"`, line 1810:

```
    tool(self)
```

File `"/usr/lib/scons/SCons/Tool/__init__.py"`, line 303:

```
    self.generate(env, *args, **kw)
```

File `"/root/gem5-SALAM/site_scons/site_tools/git.py"`, line 116:

```
    install_style_hooks(env)
```

File `"/root/gem5-SALAM/site_scons/site_tools/git.py"`, line 111:

```
    hook_install("pre-commit", git_style_script)
```

File `"/root/gem5-SALAM/site_scons/site_tools/git.py"`, line 77:

```
    os.mkdir(git_hooks.get_abspath())
```

```
root@7e6b2a3a4a52:~/gem5-SALAM# ls -al
```

total 60

```
drwxr-xr-x 1 501 dialout 334 Dec 25 10:30 .
drwx----- 1 root root 36 Dec 25 10:56 ..
drwxr-xr-x 1 501 dialout 142 Dec 25 10:31 .git
-rw-r--r-- 1 501 dialout 665 Dec 25 10:30 .gitignore
-rw-r--r-- 1 501 dialout 206 Dec 25 10:30 .hgignore
-rw-r--r-- 1 501 dialout 1646 Dec 25 10:30 .hgtags
-rw-r--r-- 1 501 dialout 2332 Dec 25 10:30 COPYING
-rw-r--r-- 1 501 dialout 1477 Dec 25 10:30 LICENSE
-rw-r--r-- 1 501 dialout 1651 Dec 25 10:30 README
-rw-r--r-- 1 501 dialout 5526 Dec 25 10:31 README.md
-rwxr-xr-x 1 501 dialout 27745 Dec 25 10:30 SConstruct
drwxr-xr-x 1 501 dialout 128 Dec 25 10:30 benchmarks
drwxr-xr-x 1 501 dialout 460 Dec 25 10:30 build_opts
drwxr-xr-x 1 501 dialout 202 Dec 25 10:30 components_library
drwxr-xr-x 1 501 dialout 148 Dec 25 10:30 configs
drwxr-xr-x 1 501 dialout 20 Dec 25 10:30 docker
drwxr-xr-x 1 501 dialout 196 Dec 25 10:56 docs
drwxr-xr-x 1 501 dialout 308 Dec 25 10:30 ext
```

```
drwxr-xr-x 1 501 dialout 8 Dec 25 10:30 include
drwxr-xr-x 1 501 dialout 126 Dec 25 11:14 site_scons
drwxr-xr-x 1 501 dialout 184 Dec 25 10:30 src
drwxr-xr-x 1 501 dialout 6 Dec 25 10:30 system
drwxr-xr-x 1 501 dialout 194 Dec 25 10:30 tests
drwxr-xr-x 1 501 dialout 108 Dec 25 10:30 tools
drwxr-xr-x 1 501 dialout 1384 Dec 25 10:30 util
root@7e6b2a3a4a52:~/gem5-SALAM# mv .git ..
root@7e6b2a3a4a52:~/gem5-SALAM# scons build/ARM/gem5.opt -j`nproc`
scons: Reading SConscript files ...
Checking for linker -Wl,--as-needed support... yes
Checking for compiler -Wno-c99-designator support... yes
Checking for compiler -Wno-defaulted-function-deleted support... yes
Checking for compiler -gz support... yes
Checking for linker -gz support... yes
Info: Using Python config: python3-config
Checking for C header file Python.h... yes
```

```
1 root@7e6b2a3a4a52:~$ scons build/ARM/gem5.opt -j`nproc`
build/ARM/hwacc/LLVMRead/src/instruction.hh:994:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1026:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1058:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1092:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1124:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1157:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1189:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1221:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1253:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1285:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1318:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1349:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1387:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1421:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1465:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1503:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
build/ARM/hwacc/LLVMRead/src/instruction.hh:1540:18: warning: private field 'currentCycle' is not used [-Wunused-private-field]
uint64_t currentCycle;
^
[ CXX] ARM/hwacc/HWModeling/generated/functionalUnits/double_multiplier.cc -> .o
[ CXX] ARM/hwacc/HWModeling/generated/functionalUnits/bit_register.cc -> .o
19 warnings generated.
[ CXX] ARM/hwacc/HWModeling/generated/functionalUnits/bitwise_operations.cc -> .o
1 warning generated.
[ CXX] ARM/hwacc/HWModeling/generated/functionalUnits/double_adder.cc -> .o
[ CXX] ARM/hwacc/HWModeling/generated/functionalUnits/float_divider.cc -> .o
[ CXX] ARM/hwacc/HWModeling/generated/functionalUnits/bit_shifter.cc -> .o
[ CXX] ARM/hwacc/HWModeling/generated/functionalUnits/integer_multiplier.cc -> .o
282 warnings generated.
[ CXX] ARM/hwacc/HWModeling/generated/functionalUnits/integer_adder.cc -> .o
[ CXX] ARM/hwacc/HWModeling/generated/functionalUnits/double_divider.cc -> .o
[ CXX] ARM/hwacc/HWModeling/generated/functionalUnits/float_adder.cc -> .o
[ CXX] ARM/hwacc/HWModeling/generated/functionalUnits/float_multiplier.cc -> .o
```

```

[ SHCC] softfloat/s_subM.c -> .os
[ SHCC] softfloat/s_subM.c -2 .os
[ SHCC] softfloat/ui32_to_f128.c -> .os
[ SHCC] softfloat/ui32_to_f16.c ->>.os
[ SHCC] softfloat/ui32_to_f32.c ->>.os
[ SHCC] softfloat/ui32_to_f64.c ->>.os
[ SHCC] softfloat/ui64_to_f128.c -> .os
[ SHCC] softfloat/ui64_to_f16.c -t .os
[ SHCC] softfloat/ui64_to_f32.c -t .os
[ SHCC] softfloat/ui64_to_f64.c -t .os
[ AR] -i softfloat/libsoftfloat.a
[ RANLIB] -i softfloat/libsoftfloat.a
[ LINK] -i ARM/gem5.opt
scons: done building targets.
*** Summary of Warnings ***
Warning: Header file <png.h> not found.
        This host has no libpng library.
        Disabling support for PNG framebuffers.
Warning: Couldn't find HDF5 C++ libraries. Disabling HDF5 support.
root@7e6b2a3a4a52:~/gem5-SALAM# scons build/ARM/gem5.debug -j`nproc`
scons: Reading SConscript files

```

为了使用系统验证基准，需要安装 ARM GCC 交叉编译器

```
apt-get install gcc-multilib gcc-arm-none-eabi
```

编译 bfs 测例

```

$ cd $M5_PATH/benchmarks/sys_validation/
$ ls
Makefile  bfs  fft  gemm  md_grid  md_knn  mergesort  nw  spmv  stencil2d  stencil3d
$ cd bfs
$ ls
Makefile  bfs_clstr_hw_defines.h  config.yml  configs  defines.h  hw  sw
$ make

```

然后进行运行测试

```
$M5_PATH/tools/run_system.sh --bench bfs --bench-path benchmarks/sys_validation/bfs
```

```
root@7e6b2a3a4a52: ...  
**** REAL SIMULATION ****  
build/ARM/dev/arm/energy_ctrl.cc:252: warn: Existing EnergyCtrl, but no enabled DVFSHandler found.  
build/ARM/sim/simulate.cc:107: info: Entering event queue @ 0. Starting simulation...  
*****  
system.bfs_clstr.bfs.llvm_interface  
Total Area: 2287.43  
Total Power Static: 48.4273  
  
Total Power Dynamic: 542.081  
===== Performance Analysis =====  
Setup Time: 0h 0m 0s 4ms 143us  
Simulation Time (Total): 0h 0m 0s 596ms  
Simulation Time (Active): 0h 0m 0s 73ms  
Queue Processing Time: 0h 0m 0s 72ms  
Scheduling Time: 0h 0m 0s 36ms  
Computation Time: 0h 0m 0s 9ms  
System Clock: 0.16Hz  
Runtime: 15600 cycles  
Runtime: 156 us  
Stalls: 0 cycles  
Executed Nodes: 15599 cycles  
  
*****  
system.bfs_clstr.top.llvm_interface  
Total Area: 251.85  
Total Power Static: 0.754787  
  
Total Power Dynamic: 3.70915  
===== Performance Analysis =====  
Setup Time: 0h 0m 0s 27ms 174us  
Simulation Time (Total): 0h 0m 0s 664ms  
Simulation Time (Active): 0h 0m 0s 9ms  
Queue Processing Time: 0h 0m 0s 7ms  
Scheduling Time: 0h 0m 0s 4ms  
Computation Time: 0h 0m 0s 0ms  
System Clock: 0.16Hz  
Runtime: 17489 cycles  
Runtime: 174.89 us  
Stalls: 0 cycles  
Executed Nodes: 17488 cycles  
  
Exiting @ tick 681163000 because m5_exit instruction encountered  
root@7e6b2a3a4a52:~/gem5-SALAM#
```

\$M5_PATH/tools/run_system.sh --bench fft --bench-path benchmarks/sys_validation/fft


```
root@7e6b2a3a4a52: ...  
build/ARM/mem/coherent_xbar.cc:140: warn: CoherentXBar system.fft_clstr.coherency_bus has no snooping ports attached!  
**** REAL SIMULATION ****  
build/ARM/dev/arm/energy_ctrl.cc:252: warn: Existing EnergyCtrl, but no enabled DVFSHandler found.  
build/ARM/sim/simulate.cc:107: info: Entering event queue @ 0. Starting simulation...  
*****  
system.fft_clstr.fft.llvm_interface  
Total Area: 1759.17  
Total Power Static: 290.869
```

```
Total Power Dynamic: 1512.8  
===== Performance Analysis =====  
Setup Time: 0h 0m 0s 4ms 9us  
Simulation Time (Total): 0h 0m 2s 698ms  
Simulation Time (Active): 0h 0m 0s 282ms  
Queue Processing Time: 0h 0m 0s 273ms  
Scheduling Time: 0h 0m 0s 139ms  
Computation Time: 0h 0m 0s 31ms  
System Clock: 0.16Hz  
Runtime: 86035 cycles  
Runtime: 860.35 us  
Stalls: 0 cycles  
Executed Nodes: 86034 cycles
```

```
*****  
system.fft_clstr.top.llvm_interface  
Total Area: 352.59  
Total Power Static: 4.08379
```

```
Total Power Dynamic: 20.0685  
===== Performance Analysis =====  
Setup Time: 0h 0m 0s 27ms 899us  
Simulation Time (Total): 0h 0m 2s 929ms  
Simulation Time (Active): 0h 0m 0s 49ms  
Queue Processing Time: 0h 0m 0s 39ms  
Scheduling Time: 0h 0m 0s 17ms  
Computation Time: 0h 0m 0s 3ms  
System Clock: 0.16Hz  
Runtime: 93824 cycles  
Runtime: 938.24 us  
Stalls: 0 cycles  
Executed Nodes: 93823 cycles
```

```
Exiting @ tick 6414695000 because m5_exit instruction encountered
```

```
$M5_PATH/tools/run_system.sh --bench gemm --bench-path benchmarks/sys_validation/gemm
```

**** REAL SIMULATION ****

```
build/ARM/dev/arm/energy_ctrl.cc:252: warn: Existing EnergyCtrl, but no enabled DVFSHan
build/ARM/sim/simulate.cc:107: info: Entering event queue @ 0. Starting simulation...
```

```
system.gemm_clstr.gemm.llvm_interface
```

Total Area: 39679.6

Total Power Static: 2379.68

Total Power Dynamic: 30006.4

===== Performance Analysis =====

```
Setup Time:                0h 0m 0s 23ms 531us
Simulation Time (Total):    0h 0m 12s 864ms
Simulation Time (Active):   0h 0m 6s 288ms
    Queue Processing Time:  0h 0m 6s 273ms
        Scheduling Time:    0h 0m 3s 65ms
        Computation Time:   0h 0m 0s 608ms
System Clock:               0.1GHz
Runtime:                    131462 cycles
Runtime:                    1314.62 us
Stalls:                     0 cycles
Executed Nodes:             131461 cycles
```

```
system.gemm_clstr.top.llvm_interface
```

Total Area: 201.48

Total Power Static: 6.15258

Total Power Dynamic: 30.2348

===== Performance Analysis =====

```
Setup Time:                0h 0m 0s 27ms 252us
Simulation Time (Total):    0h 0m 13s 162ms
Simulation Time (Active):   0h 0m 0s 88ms
    Queue Processing Time:  0h 0m 0s 72ms
        Scheduling Time:    0h 0m 0s 29ms
        Computation Time:   0h 0m 0s 6ms
System Clock:               0.1GHz
Runtime:                    141082 cycles
Runtime:                    1410.82 us
Stalls:                     0 cycles
```

Executed Nodes: 141081 cycles

```
$M5_PATH/tools/run_system.sh --bench md_grid --bench-path benchmarks/sys_validation/md_
```

**** REAL SIMULATION ****

```
build/ARM/dev/arm/energy_ctrl.cc:252: warn: Existing EnergyCtrl, but no enabled DVFSHan
build/ARM/sim/simulate.cc:107: info: Entering event queue @ 0. Starting simulation...
```

```
system.md_grid_clstr.md_grid.llvm_interface
```

```
Total Area: 4718.41
```

```
Total Power Static: 322.876
```

```
Total Power Dynamic: 3862.24
```

```
===== Performance Analysis =====
```

```
Setup Time:                0h 0m 0s 11ms 49us
Simulation Time (Total):    0h 0m 13s 759ms
Simulation Time (Active):   0h 0m 1s 415ms
    Queue Processing Time:  0h 0m 1s 365ms
        Scheduling Time:    0h 0m 0s 740ms
        Computation Time:   0h 0m 0s 165ms
System Clock:              0.1GHz
Runtime:                   473346 cycles
Runtime:                   4733.46 us
Stalls:                    0 cycles
Executed Nodes:            473345 cycles
```

```
system.md_grid_clstr.top.llvm_interface
```

```
Total Area: 201.48
```

```
Total Power Static: 20.7912
```

```
Total Power Dynamic: 102.171
```

```
===== Performance Analysis =====
```

```
Setup Time:                0h 0m 0s 27ms 267us
Simulation Time (Total):    0h 0m 13s 867ms
Simulation Time (Active):   0h 0m 0s 226ms
    Queue Processing Time:  0h 0m 0s 178ms
        Scheduling Time:    0h 0m 0s 79ms
        Computation Time:   0h 0m 0s 12ms
System Clock:              0.1GHz
Runtime:                   476410 cycles
Runtime:                   4764.1 us
Stalls:                    0 cycles
Executed Nodes:            476409 cycles
```

```
$M5_PATH/tools/run_system.sh --bench md_knn --bench-path benchmarks/sys_validation/md_k
```

**** REAL SIMULATION ****

```
build/ARM/dev/arm/energy_ctrl.cc:252: warn: Existing EnergyCtrl, but no enabled DVFSHan
build/ARM/sim/simulate.cc:107: info: Entering event queue @ 0. Starting simulation...
```

```
system.mdknn_clstr.md_knn.llvm_interface
```

Total Area: 2502.76

Total Power Static: 74.7734

Total Power Dynamic: 982.59

===== Performance Analysis =====

```
Setup Time:                0h 0m 0s 6ms 428us
Simulation Time (Total):    0h 0m 5s 460ms
Simulation Time (Active):   0h 0m 2s 972ms
    Queue Processing Time:  0h 0m 2s 964ms
        Scheduling Time:    0h 0m 1s 869ms
            Computation Time: 0h 0m 0s 35ms
System Clock:              0.1GHz
Runtime:                   65605 cycles
Runtime:                   656.05 us
Stalls:                    0 cycles
Executed Nodes:            65604 cycles
```

```
system.mdknn_clstr.top.llvm_interface
```

Total Area: 402.96

Total Power Static: 2.99226

Total Power Dynamic: 14.7045

===== Performance Analysis =====

```
Setup Time:                0h 0m 0s 28ms 198us
Simulation Time (Total):    0h 0m 5s 602ms
Simulation Time (Active):   0h 0m 0s 37ms
    Queue Processing Time:  0h 0m 0s 29ms
        Scheduling Time:    0h 0m 0s 14ms
            Computation Time: 0h 0m 0s 2ms
System Clock:              0.1GHz
Runtime:                   68941 cycles
Runtime:                   689.41 us
Stalls:                    0 cycles
Executed Nodes:            68940 cycles
```

```
$M5_PATH/tools/run_system.sh --bench nw --bench-path benchmarks/sys_validation/nw
```

**** REAL SIMULATION ****

```
build/ARM/dev/arm/energy_ctrl.cc:252: warn: Existing EnergyCtrl, but no enabled DVFSHan
build/ARM/sim/simulate.cc:107: info: Entering event queue @ 0. Starting simulation...
```

```
system.nw_clstr.nw.llvm_interface
```

```
Total Area: 26577.1
```

```
Total Power Static: 4058.15
```

```
Total Power Dynamic: 7686.08
```

```
===== Performance Analysis =====
```

```
Setup Time:                0h 0m 0s 4ms 947us
Simulation Time (Total):    0h 0m 3s 244ms
Simulation Time (Active):   0h 0m 0s 687ms
    Queue Processing Time:  0h 0m 0s 680ms
        Scheduling Time:    0h 0m 0s 361ms
        Computation Time:   0h 0m 0s 144ms
System Clock:              0.1GHz
Runtime:                   66962 cycles
Runtime:                   669.62 us
Stalls:                    0 cycles
Executed Nodes:            66961 cycles
```

```
system.nw_clstr.top.llvm_interface
```

```
Total Area: 251.85
```

```
Total Power Static: 2.92931
```

```
Total Power Dynamic: 14.3951
```

```
===== Performance Analysis =====
```

```
Setup Time:                0h 0m 0s 27ms 120us
Simulation Time (Total):    0h 0m 3s 272ms
Simulation Time (Active):   0h 0m 0s 34ms
    Queue Processing Time:  0h 0m 0s 27ms
        Scheduling Time:    0h 0m 0s 12ms
        Computation Time:   0h 0m 0s 2ms
System Clock:              0.1GHz
Runtime:                   67290 cycles
Runtime:                   672.9 us
Stalls:                    0 cycles
Executed Nodes:            67289 cycles
```

```
$M5_PATH/tools/run_system.sh --bench spmv --bench-path benchmarks/sys_validation/spmv
```

**** REAL SIMULATION ****

```
build/ARM/dev/arm/energy_ctrl.cc:252: warn: Existing EnergyCtrl, but no enabled DVFSHan
build/ARM/sim/simulate.cc:107: info: Entering event queue @ 0. Starting simulation...
```

```
system.spmv_clstr.spmv.llvm_interface
```

Total Area: 1507.32

Total Power Static: 25.6176

Total Power Dynamic: 342.257

===== Performance Analysis =====

```
Setup Time:                0h 0m 0s 6ms 43us
Simulation Time (Total):    0h 0m 0s 582ms
Simulation Time (Active):   0h 0m 0s 357ms
    Queue Processing Time:  0h 0m 0s 356ms
        Scheduling Time:    0h 0m 0s 189ms
            Computation Time: 0h 0m 0s 5ms
System Clock:               0.1GHz
Runtime:                    8342 cycles
Runtime:                    83.42 us
Stalls:                     0 cycles
Executed Nodes:             8341 cycles
```

```
system.spmv_clstr.top.llvm_interface
```

Total Area: 302.22

Total Power Static: 0.516433

Total Power Dynamic: 2.53784

===== Performance Analysis =====

```
Setup Time:                0h 0m 0s 27ms 128us
Simulation Time (Total):    0h 0m 0s 697ms
Simulation Time (Active):   0h 0m 0s 7ms
    Queue Processing Time:  0h 0m 0s 6ms
        Scheduling Time:    0h 0m 0s 3ms
            Computation Time: 0h 0m 0s 0ms
System Clock:               0.1GHz
Runtime:                    12062 cycles
Runtime:                    120.62 us
Stalls:                     0 cycles
Executed Nodes:             12061 cycles
```