MSCS-531-M50

Using GEM5 with a "Hello World" Program for the x86 ISA

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MSCS-531-M50: Computer Architecture and Design

Introduction to gem5

Note: This portion was done in week1 so I just grabbed from week 1 documment

gem5 is a versatile, open-source tool widely used in the field of computer architecture research. It allows for the simulation and modeling of a wide range of computer systems, from basic CPUs to complex multi-core architectures with intricate memory hierarchies and network-on-chip systems. One of the key advantages of gem5 is its support for multiple instruction set architectures (ISAs) like x86, ARM, and RISC-V, making it highly adaptable for different research needs.

A significant feature of gem5 is its ability to run both full-system simulations, which replicate the entire computing environment including the operating system, and system-call emulation, which focuses on user-level programs while utilizing the host system's kernel. This makes gem5 particularly useful for testing new architectural ideas, optimizing system performance, and analyzing energy efficiency and security aspects. Researchers can explore and refine new hardware designs using gem5 before committing to the costly process of physical implementation.

References:

Binkert, N., Beckmann, B., Black, G., Reinhardt, S. K., Saidi, A., Basu, A., ... & Wood, D. A. (2011). The gem5 simulator. ACM SIGARCH Computer Architecture News, 39(2), 1-7. doi:10.1145/2024716.2024718.

"The gem5 Simulator System." gem5.org. Available at: https://www.gem5.org/

Environment Setup

My environment my already setup in the previous week assignment. But I choose to build a new architecture for this assignment to get more practice. For this I made sure I had everything I needed already installedd. I checked the version of the required dependencies

```
sandesh@sandesh-Inspiron-7373:~/Sandesh_CumberLands_Assignments/Computer_Architecture/Week2$ scons --version
SCons by Steven Knight et al.:
        SCons: v4.0.1.c289977f8b34786ab6c334311e232886da7e8df1, 2020-07-17 01:50:03, by bdbaddog on ProDog2020
        SCons path: ['/usr/lib/python3/dist-packages/SCons']
Copyright (c) 2001 - 2020 The SCons Foundation
sandesh@sandesh-Inspiron-7373:~/Sandesh_CumberLands_Assignments/Computer_Architecture/Week2$ gcc --version
gcc (Ubuntu 11.4.0-1ubuntu1~22.04) 11.4.0
Copyright (C) 2021 Free Software Foundation, Inc.
This is free software; see the source for copying conditions.  There is NO
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.

sandesh@sandesh-Inspiron-7373:~/Sandesh_CumberLands_Assignments/Computer_Architecture/Week2$ g++ --version
g++ (Ubuntu 11.4.0-1ubuntu1~22.04) 11.4.0
Copyright (C) 2021 Free Software Foundation, Inc.
This is free software; see the source for copying conditions.  There is NO
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
```

Cloned the gem5 repository

I cloned the repository from the link given in the assignment file which is
git clone https://gem5.googlesource.com/public/gem5

```
sandesh@sandesh-Inspiron-7373:~/Sandesh_CumberLands_Assignments/Computer_Architecture/Week2$ git clone https://gem5.googlesource.com/public/gem5
Cloning into 'gem5'...
remote: Total 270560 (delta 202246), reused 270560 (delta 202246)
Receiving objects: 100% (270560/270560), 228.00 MiB | 24.28 MiB/s, done.
Resolving deltas: 100% (202246/202246), done.
sandesh@sandesh-Inspiron-7373:~/Sandesh_CumberLands_Assignments/Computer_Architecture/Week2$ ls
gem5
sandesh@sandesh-Inspiron-7373:~/Sandesh_CumberLands_Assignments/Computer_Architecture/Week2$ cd gem5
sandesh@sandesh-Inspiron-7373:~/Sandesh_CumberLands_Assignments/Computer_Architecture/Week2/gem5$ ls
build_opts        ext                      pyproject.toml      site_scons
build_tools       include                  README              src
CODE-OF-CONDUCT.md KCONFIG.md                                 RELEASE-NOTES.md  system
configs           LICENSE                  requirements.txt   TESTING.md
CONTRIBUTING.md   MAINTAINERS.yaml         SConsopts          tests
COPYING           optional-requirements.txt SConstruct        util
sandesh@sandesh-Inspiron-7373:~/Sandesh_CumberLands_Assignments/Computer_Architecture/Week2/gem5$ scons build/X86/gem5.opt -j8
scons: Reading SConscript files ...
```

Building gem5 for x86

For building, I ran the command as per the assignment file which is
scons build/X86/gem5.opt -j4
In my case, I build with –j8 configuration as I have 8 cores
scons build/X86/gem5.opt -j8

Writing the "hello world " program

After building, I created the file hello.c and saved my file for printing "Hello World"

Compiling the Program

For Compiling, I used command below which helped me to create executable in the directry named "hello"
gcc hello.c -o hello

Running the Program in Gem5

Setup a simple simulation script

I created python file named run_hello.py with the following script

```python
from m5.objects import *

# Create the system
system = System()
system.clk_domain = SrcClockDomain()
system.clk_domain.clock = "1GHz"
system.clk_domain.voltage_domain = VoltageDomain()

# Memory configuration
system.mem_mode = "timing"
system.mem_ranges = [AddrRange("512MB")]
system.mem_ctrl = DDR3_1600_8x8()
system.mem_ctrl.range = system.mem_ranges[0]

# CPU configuration
system.cpu = TimingSimpleCPU()
system.cpu.icache = L1_ICache(size="32kB")
system.cpu.dcache = L1_DCache(size="32kB")

# Connecting CPU and memory
system.membus = SystemXBar()
system.cpu.icache_port = system.membus.slave
system.cpu.dcache_port = system.membus.slave
system.cpu.createInterruptController()

# Setting up workload
system.workload = SEWorkload.init_compatible("hello")
system.cpu.workload = system.workload
system.cpu.createThreads()

# Simulation configuration
root = Root(full_system=False, system=system)
m5.instantiate()

print("Beginning simulation!")
exit_event = m5.simulate()

print("Exiting @ tick {} because {}".format(
    m5.curTick(), exit_event.getCause()))
```

Run Gem5 Simulation

For running the simulation I used the following command and **I was able to see the "Hello world!" message and some simulation statistics**.

```
/build/X86/gem5.opt configs/deprecated/example/se.py -c hello
gem5 Simulator System.  https://www.gem5.org
gem5 is copyrighted software; use the --copyright option for details.

gem5 version 23.0.0.1
gem5 compiled Sep 21 2024 11:21:07
gem5 started Sep 21 2024 11:55:09
gem5 executing on sandesh-Inspiron-7373, pid 30398
command line: ./build/X86/gem5.opt configs/deprecated/example/se.py -c hello

warn: The `get_runtime_isa` function is deprecated. Please migrate away from using this function.
warn: The se.py script is deprecated. It will be removed in future releases of  gem5.
warn: The `get_runtime_isa` function is deprecated. Please migrate away from using this function.
Global frequency set at 1000000000000 ticks per second
warn: No dot file generated. Please install pydot to generate the dot file and pdf.
src/mem/dram_interface.cc:690: warn: DRAM device capacity (8192 Mbytes) does not match the address range assigned (512 Mbytes)
src/base/statistics.hh:279: warn: One of the stats is a legacy stat. Legacy stat is a stat that does not belong to any statistics::Group. Legacy stat is deprecated.
system.remote_gdb: Listening for connections on port 7000
**** REAL SIMULATION ****
src/sim/simulate.cc:194: info: Entering event queue @ 0.  Starting simulation...
src/sim/mem_state.cc:443: info: Increasing stack size by one page.
src/sim/syscall_emul.cc:74: warn: ignoring syscall mprotect(...)
src/sim/syscall_emul.cc:74: warn: ignoring syscall set_robust_list(...)
src/sim/syscall_emul.cc:74: warn: ignoring syscall rseq(...)
src/sim/syscall_emul.cc:74: warn: ignoring syscall mprotect(...)
src/sim/syscall_emul.cc:74: warn: ignoring syscall mprotect(...)
src/sim/syscall_emul.cc:74: warn: ignoring syscall mprotect(...)
Hello World!
sandesh@sandesh-Inspiron-7373:~/Sandesh_CumberLands_Assignments/Computer_Architecture/Week2/gem5$
```

Challenges and solutions

Initially when I tried to run the simulation, I provided the command and got small error as se.py location had been changed in this version of gem5 as it was deprecated: ./build/X86/gem5.opt configs/example/se.py -c hello

Error I got:

```
sandesh@sandesh-Inspiron-7373:~/Sandesh_CumberLands_Assignments/Computer_Archite
cture/Week2/gem5$ ./build/X86/gem5.opt configs/example/se.py -c hello
gem5 Simulator System.  https://www.gem5.org
gem5 is copyrighted software; use the --copyright option for details.

gem5 version 23.0.0.1
gem5 compiled Sep 21 2024 11:21:07
gem5 started Sep 21 2024 11:53:16
gem5 executing on sandesh-Inspiron-7373, pid 30380
command line: ./build/X86/gem5.opt configs/example/se.py -c hello

fatal: The 'configs/example/se.py' script has been deprecated. It can be found i
n 'configs/deprecated/example' if required. Its usage should be avoided as it wi
ll be removed in future releases of gem5.
```

I fixed the path and entered the build command again as : build/X86/gem5.opt configs/deprecated/example/se.py -c hello

This worked and I got the expected output.

Since this was basic simulation, luckily I did not get more complication and overall process was smooth other than it took almost an hour to build the architecture.