

Instalação do Compilador P4 no sistema Ubuntu 18.04.5 LTS



```
root@feec:~# lsb_release -a
No LSB modules are available.
Distributor ID: Ubuntu
Description:    Ubuntu 18.04.5 LTS
Release:        18.04
Codename:       bionic
root@feec:~#
```

Objetivo:

Instalar o compilador P4 e as ferramentas: protobuf, p4c e bmv2, entre outras que serão utilizadas neste tutorial, auxiliando a implantação de um ambiente que utilize a linguagem P4 e ferramentas que auxiliam na programação de interfaces, entre outras programações que podem ser feitas com este ambiente.

Importante:

Este tutorial foi feito em uma máquina física e não em ambiente “virtualizado”, a máquina utilizada foi:

Intel (R) Core (TM) i3-3240 CPU @ 3.40GHz

Memória RAM: 6GB – HD: 300GB

Procedimento de Instalação e preparação do ambiente

1. Atualizar o sistema e reiniciar o sistema:

```
apt update && apt upgrade -y && reboot
```

2. Instalando algumas ferramentas auxiliares que não constam na versão 18 do Ubuntu:

```
apt install net-tools ssh vim nmap htop tree python-pip -y
```

3. Instalando algumas ferramentas necessárias para o ambiente:

```
sudo apt-get install g++ git automake libtool libgc-dev bison flex
libfl-dev libgmp-dev libboost-dev libboost-iostreams-dev pkg-config
python python-scapy python-ipaddr c url wget tcpdump cmake -y
```

4. Instalando a biblioteca do Protobuf, que será necessário para funcionar o ambiente, caso já tenha essas ferramentas, siga para a etapa 5º, mas confira antes:

```
sudo apt-get install autoconf automake libtool curl make g++ unzip -y
```

5. Instalando o Gmock, no diretório dentro de /home, porém você poderá escolher o diretório que preferir:

```
cd /home && git clone git://github.com/paulsapps/gmock-1.7.0
```

```
root@feec:~# cd /home && git clone git://github.com/paulsapps/gmock-1.7.0
Cloning into 'gmock-1.7.0'...
remote: Enumerating objects: 306, done.
remote: Total 306 (delta 0), reused 0 (delta 0), pack-reused 306
Receiving objects: 100% (306/306), 1.60 MiB | 824.00 KiB/s, done.
Resolving deltas: 100% (85/85), done.
root@feec:/home#
```

6. Acessando o diretório o Gmock e efetuando sua compilação:

```
cd gmock-1.7.0/make/ && make
```

```
g++ -isystem ../gtest/include -isystem ../include -g -Wall -Wextra -pthread -c ../test/gmock_test.cc
g++ -isystem ../gtest/include -isystem ../include -I../gtest -I.. -g -Wall -Wextra -pthread \
-c ../src/gmock-all.cc
g++ -isystem ../gtest/include -isystem ../include -I../gtest -I.. -g -Wall -Wextra -pthread \
-c ../gtest/src/gtest-all.cc
g++ -isystem ../gtest/include -isystem ../include -I../gtest -I.. -g -Wall -Wextra -pthread \
-c ../src/gmock_main.cc
ar rv gmock_main.a gmock-all.o gtest-all.o gmock_main.o
ar: criando gmock_main.a
a - gmock-all.o
a - gtest-all.o
a - gmock_main.o
g++ -isystem ../gtest/include -isystem ../include -g -Wall -Wextra -pthread -lpthread gmock_test.o gmock_main.a -o gmock_test
root@feec:/home/gmock-1.7.0/make#
```

7. Detectando unidade do Gmock, dentro do diretório: /home/gmock-1.7.0/make

```
./gmock_test
```

```
root@feec:/home/gmock-1.7.0/make# ls -lha
total 12M
drwxr-xr-x  2 root root  4,0K abr 20 23:53 .
drwxr-xr-x 12 root root  4,0K abr 20 23:47 ..
-rw-r--r--  1 root root  1,5M abr 20 23:53 gmock-all.o
-rw-r--r--  1 root root  4,4M abr 20 23:53 gmock_main.a
-rw-r--r--  1 root root 132K abr 20 23:53 gmock_main.o
-rwxr-xr-x  1 root root  2,3M abr 20 23:53 gmock_test
-rw-r--r--  1 root root 513K abr 20 23:53 gmock_test.o
-rw-r--r--  1 root root  2,6M abr 20 23:53 gtest-all.o
-rw-r--r--  1 root root  3,6K abr 20 23:47 Makefile
root@feec:/home/gmock-1.7.0/make# ./gmock_test
```

Importante:

Os resultados devem ser semelhantes ao da figura 1º

```
Running main() from gmock_main.cc
[=====] Running 13 tests from 3 test cases.
[-----] Global test environment set-up.
[-----] 6 tests from InitGoogleMockTest
[ RUN      ] InitGoogleMockTest.ParsesInvalidCommandLine
[ OK       ] InitGoogleMockTest.ParsesInvalidCommandLine (0 ms)
[ RUN      ] InitGoogleMockTest.ParsesEmptyCommandLine
[ OK       ] InitGoogleMockTest.ParsesEmptyCommandLine (0 ms)
[ RUN      ] InitGoogleMockTest.ParsesSingleFlag
[ OK       ] InitGoogleMockTest.ParsesSingleFlag (0 ms)
[ RUN      ] InitGoogleMockTest.ParsesUnrecognizedFlag
[ OK       ] InitGoogleMockTest.ParsesUnrecognizedFlag (0 ms)
[ RUN      ] InitGoogleMockTest.ParsesGoogleMockFlagAndUnrecognizedFlag
[ OK       ] InitGoogleMockTest.ParsesGoogleMockFlagAndUnrecognizedFlag (0 ms)
[ RUN      ] InitGoogleMockTest.CallsInitGoogleTest
[ OK       ] InitGoogleMockTest.CallsInitGoogleTest (0 ms)
[-----] 6 tests from InitGoogleMockTest (1 ms total)

[-----] 6 tests from WideInitGoogleMockTest
[ RUN      ] WideInitGoogleMockTest.ParsesInvalidCommandLine
[ OK       ] WideInitGoogleMockTest.ParsesInvalidCommandLine (0 ms)
[ RUN      ] WideInitGoogleMockTest.ParsesEmptyCommandLine
[ OK       ] WideInitGoogleMockTest.ParsesEmptyCommandLine (0 ms)
[ RUN      ] WideInitGoogleMockTest.ParsesSingleFlag
[ OK       ] WideInitGoogleMockTest.ParsesSingleFlag (0 ms)
[ RUN      ] WideInitGoogleMockTest.ParsesUnrecognizedFlag
[ OK       ] WideInitGoogleMockTest.ParsesUnrecognizedFlag (0 ms)
[ RUN      ] WideInitGoogleMockTest.ParsesGoogleMockFlagAndUnrecognizedFlag
[ OK       ] WideInitGoogleMockTest.ParsesGoogleMockFlagAndUnrecognizedFlag (0 ms)
[ RUN      ] WideInitGoogleMockTest.CallsInitGoogleTest
[ OK       ] WideInitGoogleMockTest.CallsInitGoogleTest (0 ms)
[-----] 6 tests from WideInitGoogleMockTest (0 ms total)

[-----] 1 test from FlagTest
[ RUN      ] FlagTest.IsAccessibleInCode
[ OK       ] FlagTest.IsAccessibleInCode (0 ms)
[-----] 1 test from FlagTest (0 ms total)

[-----] Global test environment tear-down
[=====] 13 tests from 3 test cases ran. (1 ms total)
[ PASSED  ] 13 tests.
root@feec:/home/gmock-1.7.0/make#
```

Figura 1º

8 . Por uma boa prática, renomeie o diretório do Gmok, conforme a ilustração a seguir, utilizando os comandos:

```
cd /home/ && mv /home/gmock-1.7.0/ gmock && ls -lha /home/ | grep gmo
```

```
drwxr-xr-x 12 root root 4,0K abr 20 23:47 gmock
```

9. Nesta etapa iremos fazer o download e instalação do pacote: **protobuf** (Google), onde possui muitas versões no site oficial, porém na fonte original deste tutorial é usada a versão **3.2.0**, porém com esta versão tivemos problemas durante o make check, já a versão **3.7.1**, o resultado foi positivo e não gerou erros, execute os comandos:

```
wget https://github.com/protocolbuffers/protobuf/archive/v3.7.1.zip  
cd /home/ && git clone https://github.com/google/protobuf.git
```

10. Crie o diretório p4 dentro de /home e mova o arquivo v3.7.1.zip para o diretório p4

```
mkdir p4 && mv v3.7.1.zip p4/
```

11. Extraíndo o protobuf dentro do diretório p4

```
cd p4/ && unzip v3.7.1.zip
```

12. Dentro do diretório /home, copie o diretório gmok para o diretório protobuf

```
cp -R /home/gmock/ /home/p4/protobuf-3.7.1/
```

13. Acesse o diretório: /home/protobuf-3.7.1/gmock/make e execute o comando a seguir:

```
./gmock_test
```

Importante:

O resultado deverá ser semelhante ao da figura 1º, porém a saída do make check é muito importante, onde todos os módulos precisam retornar como “PASS”, caso contrário, ocorrerão erros durante o tutorial, se isso acontecer, não siga em frente, resolva os problemas antes.

14. Acesse o diretório: /home/p4/protobuf-3.7.1 e execute os comandos a seguir:

```
./autogen.sh && ./configure
```

- 15.** Execute os comandos a seguir e dependendo do seu hardware, este procedimento deverá levar alguns minutos:

```
make && make check
```

Importante:

Resultado da etapa **15º** na figura 2º

```
protobuf/compiler/objectivec/objectivec_helpers.o google/protobuf/compiler/objectivec/objectivec_map_f
ield.o google/protobuf/compiler/objectivec/objectivec_message.o google/protobuf/compiler/objectivec/ob
jectivec_message_field.o google/protobuf/compiler/objectivec/objectivec_oneof.o google/protobuf/compil
er/objectivec/objectivec_primitive_field.o google/protobuf/compiler/php/php_generator.o google/protobu
f/compiler/python/python_generator.o google/protobuf/compiler/ruby/ruby_generator.o google/protobuf/co
mpiler/csharp/csharp_doc_comment.o google/protobuf/compiler/csharp/csharp_enum.o google/protobuf/compil
er/csharp/csharp_enum_field.o google/protobuf/compiler/csharp/csharp_field_base.o google/protobuf/com
piler/csharp/csharp_generator.o google/protobuf/compiler/csharp/csharp_helpers.o google/protobuf/compil
er/csharp/csharp_map_field.o google/protobuf/compiler/csharp/csharp_message.o google/protobuf/compile
r/csharp/csharp_message_field.o google/protobuf/compiler/csharp/csharp_primitive_field.o google/protob
uf/compiler/csharp/csharp_reflection_class.o google/protobuf/compiler/csharp/csharp_repeated_enum_fiel
d.o google/protobuf/compiler/csharp/csharp_repeated_message_field.o google/protobuf/compiler/csharp/cs
harp_repeated_primitive_field.o google/protobuf/compiler/csharp/csharp_source_generator_base.o google/
protobuf/compiler/csharp/csharp_wrapper_field.o
ar: `u' modifier ignored since `D' is the default (see `U')
libtool: link: ranlib .libs/libprotoc.a
libtool: link: ( cd ".libs" && rm -f "libprotoc.la" && ln -s "../libprotoc.la" "libprotoc.la" )
depbased=`echo google/protobuf/compiler/main.o | sed 's|[^/]*$|.deps/&|;s|\.o$|\.o$|'`;
g++ -DHAVE_CONFIG_H -I. -I.. -pthread -DHAVE_PTHREAD=1 -DHAVE_ZLIB=1 -Wall -Wno-sign-compare -O2 -g
-std=c++11 -DNDEBUG -MT google/protobuf/compiler/main.o -MD -MP -MF $depbased.Tpo -c -o google/protobu
f/compiler/main.o google/protobuf/compiler/main.cc &&\
mv -f $depbased.Tpo $depbased.Po
/bin/bash ../libtool --tag=CXX --mode=link g++ -pthread -DHAVE_PTHREAD=1 -DHAVE_ZLIB=1 -Wall -Wno-s
ign-compare -O2 -g -std=c++11 -DNDEBUG -pthread -o protoc google/protobuf/compiler/main.o libprotobu
f.la libprotoc.la -lz
libtool: link: g++ -pthread -DHAVE_PTHREAD=1 -DHAVE_ZLIB=1 -Wall -Wno-sign-compare -O2 -g -std=c++11 -
DNDEBUG -pthread -o .libs/protoc google/protobuf/compiler/main.o ../libs/libprotobuf.so ../libs/libpr
otoc.so -lz -pthread
make[2]: Leaving directory '/home/p4/protobuf-3.7.1/src'
make[1]: Leaving directory '/home/p4/protobuf-3.7.1'
root@feec:/home/p4/protobuf-3.7.1#
```

Figura 2º

- 16.** Para finalizar a instalação do protobuf, execute o comando abaixo, o retorno deverá ser semelhante ao da figura 3º

```
sudo make install
```

```

rt.h google/protobuf/port_def.inc google/protobuf/port_undef.inc google/protobuf/reflection.h google/protobuf/reflection_ops.h '/usr/local/include/google/protobuf'
/bin/mkdir -p '/usr/local/include/google/protobuf/compiler/js'
/usr/bin/install -c -m 644 google/protobuf/compiler/js/js_generator.h google/protobuf/compiler/js/well_known_types_embed.h '/usr/local/include/google/protobuf/compiler/js'
/bin/mkdir -p '/usr/local/include/google/protobuf/compiler/cpp'
/usr/bin/install -c -m 644 google/protobuf/compiler/cpp/cpp_generator.h '/usr/local/include/google/protobuf/compiler/cpp'
/bin/mkdir -p '/usr/local/include/google/protobuf/compiler/ruby'
/usr/bin/install -c -m 644 google/protobuf/compiler/ruby/ruby_generator.h '/usr/local/include/google/protobuf/compiler/ruby'
/bin/mkdir -p '/usr/local/include/google/protobuf/compiler/python'
/usr/bin/install -c -m 644 google/protobuf/compiler/python/python_generator.h '/usr/local/include/google/protobuf/compiler/python'
/bin/mkdir -p '/usr/local/include/google/protobuf/util'
/usr/bin/install -c -m 644 google/protobuf/util/type_resolver.h google/protobuf/util/delimited_message_util.h google/protobuf/util/field_comparator.h google/protobuf/util/field_mask_util.h google/protobuf/util/json_util.h google/protobuf/util/time_util.h google/protobuf/util/type_resolver_util.h google/protobuf/util/message_differencer.h '/usr/local/include/google/protobuf/util'
/bin/mkdir -p '/usr/local/include/google/protobuf/io'
/usr/bin/install -c -m 644 google/protobuf/io/coded_stream.h google/protobuf/io/gzip_stream.h google/protobuf/io/printer.h google/protobuf/io/stretod.h google/protobuf/io/tokenizer.h google/protobuf/io/zero_copy_stream.h google/protobuf/io/zero_copy_stream_impl.h google/protobuf/io/zero_copy_stream_impl_lite.h '/usr/local/include/google/protobuf/io'
/bin/mkdir -p '/usr/local/include/google/protobuf/compiler/csharp'
/usr/bin/install -c -m 644 google/protobuf/compiler/csharp/csharp_generator.h google/protobuf/compiler/csharp/csharp_names.h '/usr/local/include/google/protobuf/compiler/csharp'
/bin/mkdir -p '/usr/local/include/google/protobuf/compiler/php'
/usr/bin/install -c -m 644 google/protobuf/compiler/php/php_generator.h '/usr/local/include/google/protobuf/compiler/php'
/bin/mkdir -p '/usr/local/include/google/protobuf/compiler/java'
/usr/bin/install -c -m 644 google/protobuf/compiler/java/java_generator.h google/protobuf/compiler/java/java_names.h '/usr/local/include/google/protobuf/compiler/java'
/bin/mkdir -p '/usr/local/include/google/protobuf/stubs'
/usr/bin/install -c -m 644 google/protobuf/stubs/callback.h google/protobuf/stubs/bytestream.h google/protobuf/stubs/casts.h google/protobuf/stubs/common.h google/protobuf/stubs/fastmem.h google/protobuf/stubs/hash.h google/protobuf/stubs/logging.h google/protobuf/stubs/macros.h google/protobuf/stubs/mutex.h google/protobuf/stubs/once.h google/protobuf/stubs/platform_macros.h google/protobuf/stubs/port.h google/protobuf/stubs/status.h google/protobuf/stubs/stl_util.h google/protobuf/stubs/stringpiece.h google/protobuf/stubs/strutil.h google/protobuf/stubs/template_util.h '/usr/local/include/google/protobuf/stubs'
/bin/mkdir -p '/usr/local/include/google/protobuf'
/usr/bin/install -c -m 644 google/protobuf/repeated_field.h google/protobuf/service.h google/protobuf/source_context.pb.h google/protobuf/struct.pb.h google/protobuf/text_format.h google/protobuf/timestamp.pb.h google/protobuf/type.pb.h google/protobuf/unknown_field_set.h google/protobuf/wire_format.h google/protobuf/wire_format_lite.h google/protobuf/wire_format_lite_inl.h google/protobuf/wrappers.pb.h '/usr/local/include/google/protobuf'
/bin/mkdir -p '/usr/local/include/google/protobuf/compiler/objectivec'
/usr/bin/install -c -m 644 google/protobuf/compiler/objectivec/objectivec_generator.h google/protobuf/compiler/objectivec/objectivec_helpers.h '/usr/local/include/google/protobuf/compiler/objectivec'
/bin/mkdir -p '/usr/local/include/google/protobuf/compiler'
/usr/bin/install -c -m 644 google/protobuf/compiler/code_generator.h google/protobuf/compiler/command_line_interface.h google/protobuf/compiler/importer.h google/protobuf/compiler/parser.h google/protobuf/compiler/plugin.h google/protobuf/compiler/plugin.pb.h '/usr/local/include/google/protobuf/compiler'
make[2]: Leaving directory '/home/p4/protobuf-3.7.1/src'
make[1]: Leaving directory '/home/p4/protobuf-3.7.1'
root@feec:/home/p4/protobuf-3.7.1#

```

Figura 3°

17. Atualizando o cache da biblioteca compartilhada, execute o seguinte comando:

```
sudo ldconfig
```

18. Visualizando a versão do protubuf, se retornar a versão **3.7.1**, informa que o protubuf foi instalado com sucesso, execute o seguinte comando:

```
protoc --version
```

```

root@feec:/home/p4/protobuf-3.7.1# protoc --version
libprotoc 3.7.1
root@feec:/home/p4/protobuf-3.7.1#

```

19. Nesta etapa iremos instalar o p4c, execute os seguintes comandos:

```

sudo apt-get install cmake g++ git automake libtool libgc-dev bison
flex libfl-dev libgmp-dev libboost-dev libboost-iostreams-dev
libboost-graph-dev llvm pkg-config python python-scapy python-ipaddr
python-ply tcpdump

```

20. Em seguida, baixe o código-fonte do p4c:

```
cd /home && git clone --recursive https://github.com/p4lang/p4c.git
```


21. Mova o diretório p4c para o diretório p4 e execute o comando: `./bootstrap.sh`

```
mv p4c/p4/ && cd p4c/ && ./bootstrap.sh
```

```
CMake Warning at backends/bmv2/CMakeLists.txt:210 (MESSAGE):
  BMv2 PSA switch is not available, not adding PSA BMv2 tests

-- Start configuring eBPF back end
-- Detected kernel version: 4.15.0-l42-generic
-- Check LLVM version with 'llvm-config --version'
-- Found LLVM 6.0.0
CMake Warning at backends/ebpf/CMakeLists.txt:165 (message):
  Missing the libbpf dependency, disabling kernel tests. You can install
  libbpf by running './build_libbpf' in the
  /home/p4/p4c/backends/ebpf/runtime folder.

-- Added 16 tests to 'ebpf-bcc' (0 xfails)
-- Added 16 tests to 'ebpf' (1 xfails)
-- Done with configuring BPF back end
-- Added 16 tests to 'ubpf' (0 xfails)
-- Added 6 tests to 'p4' (0 xfails)
-- Added 851 tests to 'p4' (1 xfails)
-- Added 6 tests to 'p4unroll' (0 xfails)
-- Added 6 tests to 'err' (0 xfails)
-- Added 234 tests to 'err' (0 xfails)
-- Added 191 tests to 'pl4_to_l6' (0 xfails)
-- CTest parallel: -j 4
-- Configuring done
-- Generating done
-- Build files have been written to: /home/p4/p4c/build
### Configured for building in 'build' folder
root@feec:/home/p4/p4c#
```

Resultado da etapa 21°

22. Acesse o diretório **build** dentro do diretório p4c e compile com comando a seguir:

```
cmake ..
```

23. Em seguida efetue a compilação com o comando a seguir:

```
make -j4
```

Importante:

Este procedimento deverá levar alguns minutos, dependendo da configuração do seu hardware, a mesma deverá iniciar em **0%** e finalizar em **100%** sem erros, conforme as próximas ilustrações:

```

root@feec:/home/p4/p4c/build# make -j4
Scanning dependencies of target update_includes
Scanning dependencies of target linkgraphs
Scanning dependencies of target linkbmv2
Scanning dependencies of target linkp4cdpdk
[ 0%] Built target linkgraphs
[ 0%] Built target linkp4cdpdk
Scanning dependencies of target linkp4cebpf
Scanning dependencies of target linkp4cubpf
[ 0%] Built target update_includes
[ 0%] Built target linkbmv2
Scanning dependencies of target linkp4test
Scanning dependencies of target p4ctoolkit
[ 0%] Built target linkp4cubpf
[ 0%] Built target linkp4cebpf
[ 0%] Built target linkp4test
[ 1%] Building CXX object lib/CMakeFiles/p4ctoolkit.dir/unified_libp4ctoolkit_srcs_1.cpp.o
Scanning dependencies of target mkP4configdir
Scanning dependencies of target mkvldirs
Scanning dependencies of target mkp4dirs
[ 1%] Built target mkvldirs
[ 1%] Built target mkP4configdir
[ 1%] Built target mkp4dirs
Scanning dependencies of target gtest
Scanning dependencies of target p4c_driver
[ 2%] Copying p4c driver
[ 3%] Building CXX object test/CMakeFiles/gtest.dir/frameworks/gtest/googletest/src/gtest-all.cc.o
[ 3%] Built target p4c_driver
[ 5%] Linking CXX static library libgtest.a
[ 5%] Built target gtest
[ 6%] Linking CXX static library libp4ctoolkit.a
[ 6%] Built target p4ctoolkit
[ 8%] [FLEX][IRgenLexer] Building scanner with flex 2.6.4
[ 8%] [BISON][IRgenParser] Building parser with bison 3.0.4
Scanning dependencies of target irgenerator
[ 11%] Building CXX object tools/ir-generator/CMakeFiles/irgenerator.dir/unified_irgenerator_srcs_1.cpp.o
[ 11%] Building CXX object tools/ir-generator/CMakeFiles/irgenerator.dir/ir-generator.cpp.o

```

```

Scanning dependencies of target genIR
[ 13%] Generating IR class files
[ 13%] Built target genIR
[ 16%] [BISON][p4Parser] Building parser with bison 3.0.4
[ 16%] [BISON][vlParser] Building parser with bison 3.0.4
Scanning dependencies of target ir
Scanning dependencies of target midend
[ 17%] Building CXX object ir/CMakeFiles/ir.dir/unified_ir_srcs_1.cpp.o
[ 18%] Building CXX object midend/CMakeFiles/midend.dir/unified_midend_srcs_1.cpp.o
[ 20%] Running Flex on parsers/vl
[ 20%] Building CXX object ir/CMakeFiles/ir.dir/unified_ir_srcs_2.cpp.o
[ 21%] Running Flex on parsers/p4
Scanning dependencies of target frontend
[ 22%] Building CXX object frontends/CMakeFiles/frontend.dir/parsers/p4/p4lexer.cc.o
[ 23%] Building CXX object frontends/CMakeFiles/frontend.dir/parsers/p4/p4parser.cc.o
[ 25%] Building CXX object frontends/CMakeFiles/frontend.dir/parsers/vl/vllexer.cc.o
[ 26%] Building CXX object midend/CMakeFiles/midend.dir/unified_midend_srcs_2.cpp.o
[ 26%] Building CXX object frontends/CMakeFiles/frontend.dir/parsers/vl/vlparser.cpp.o
[ 27%] Linking CXX static library libir.a
[ 27%] Built target ir
[ 28%] Building CXX object frontends/CMakeFiles/frontend.dir/__/ir/ir-generated.cpp.o
[ 30%] Building CXX object frontends/CMakeFiles/frontend.dir/unified_frontend_sources_1.cpp.o
[ 31%] Building CXX object midend/CMakeFiles/midend.dir/unified_midend_srcs_3.cpp.o
[ 32%] Building CXX object frontends/CMakeFiles/frontend.dir/unified_frontend_sources_2.cpp.o
[ 33%] Building CXX object midend/CMakeFiles/midend.dir/unified_midend_srcs_4.cpp.o
[ 33%] Building CXX object frontends/CMakeFiles/frontend.dir/unified_frontend_sources_3.cpp.o
[ 35%] Building CXX object frontends/CMakeFiles/frontend.dir/unified_frontend_sources_4.cpp.o
[ 36%] Building CXX object frontends/CMakeFiles/frontend.dir/unified_frontend_sources_5.cpp.o
[ 37%] Linking CXX static library libmidend.a
[ 37%] Built target midend
[ 38%] Building CXX object frontends/CMakeFiles/frontend.dir/unified_frontend_sources_6.cpp.o
[ 40%] Building CXX object frontends/CMakeFiles/frontend.dir/unified_frontend_sources_7.cpp.o
[ 41%] Building CXX object frontends/CMakeFiles/frontend.dir/unified_frontend_sources_8.cpp.o
[ 41%] Building CXX object frontends/CMakeFiles/frontend.dir/unified_extension_frontend_sources_1.cpp.o

```


Importante:

O uso de CPU é intenso, conforme ilustra imagem abaixo utilizando o software htop, caso não tenha o mesmo instalado, instale com os comandos:

```
sudo apt update && sudo apt-get install htop -y
```

```
1 [|||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||100.0%] Tasks: 100, 183 thr; 4 running
2 [|||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||100.0%] Load average: 3.04 1.90 0.90
3 [|||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||100.0%] Uptime: 02:02:43
4 [|||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||100.0%]
Mem[||||||||||||||||||||||||||||||||||||||||||||||||||||||||| 2.48G/5.68G]
Swp[| 524K/5.86G]
```

```
Scanning dependencies of target p4c-ubpf
[ 66%] Building CXX object backends/ubpf/CMakeFiles/p4c-ubpf.dir/unified_p4c_ubpf_sources_1.cpp.o
[ 66%] Built target p4c-bm2-psa
Scanning dependencies of target p4test
[ 67%] Building CXX object backends/p4test/CMakeFiles/p4test.dir/unified_p4test_srcs_1.cpp.o
[ 68%] Linking CXX executable p4c-ebpf
[ 68%] Built target p4c-ebpf
Scanning dependencies of target p4c-graphs
[ 70%] Building CXX object backends/graphs/CMakeFiles/p4c-graphs.dir/unified_graphs_srcs_1.cpp.o
[ 71%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/_/bmv2/common/controlFlowGraph.cpp.o
[ 71%] Linking CXX executable p4test
[ 71%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/_/bmv2/common/deparsed.cpp.o
[ 72%] Linking CXX executable p4c-ubpf
[ 72%] Built target p4test
Scanning dependencies of target gtestp4c
[ 73%] Building CXX object test/CMakeFiles/gtestp4c.dir/unified_gtest_base_sources_1.cpp.o
[ 73%] Built target p4c-ubpf
[ 75%] Building CXX object test/CMakeFiles/gtestp4c.dir/unified_gtest_base_sources_2.cpp.o
[ 76%] Linking CXX executable p4c-graphs
[ 76%] Built target p4c-graphs
[ 77%] Building CXX object test/CMakeFiles/gtestp4c.dir/unified_gtest_base_sources_3.cpp.o
[ 78%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/_/bmv2/common/expression.cpp.o
[ 80%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/_/bmv2/common/extern.cpp.o
[ 81%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/_/bmv2/common/globals.cpp.o
[ 82%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/_/bmv2/common/header.cpp.o
[ 83%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/_/bmv2/common/lower.cpp.o
[ 85%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/_/bmv2/common/metermap.cpp.o
[ 86%] Linking CXX executable gtestp4c
[ 87%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/_/bmv2/common/parser.cpp.o
[ 87%] Built target gtestp4c
[ 88%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/_/bmv2/common/programStructure.cpp.o
[ 90%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/_/bmv2/psa_switch/psaSwitch.cpp.o
[ 90%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/backend.cpp.o
[ 91%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/main.cpp.o
[ 92%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/midend.cpp.o
[ 93%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/dpdkHelpers.cpp.o
[ 95%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/dpdkProgram.cpp.o
[ 96%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/dpdkVarCollector.cpp.o
[ 97%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/dpdkArch.cpp.o
[ 98%] Building CXX object backends/dpdk/CMakeFiles/p4c-dpdk.dir/dpdkAsmOpt.cpp.o
[100%] Linking CXX executable p4c-dpdk
[100%] Built target p4c-dpdk
root@feec:/home/p4/p4c/build#
```

24. Testando a unidade p4c, este processo levará alguns minutos, dependendo do seu hardware, onde dever iniciar em: **1** e finalizar em: **1399**, conforme a ilustração a seguir:

```
make check -j4
```

```

root@feec:/home/p4/p4c/build# make check -j4
Scanning dependencies of target check-all
[100%] Running tests for tag all
Test project /home/p4/p4c/build
  Start    1: cpplint
  Start    2: dpdk/testdata/p4_l6_samples/psa-action-profile1.p4
  Start    3: dpdk/testdata/p4_l6_samples/psa-action-profile2.p4
  Start    4: dpdk/testdata/p4_l6_samples/psa-action-profile3.p4
1/1399 Test #3: dpdk/testdata/p4_l6_samples/psa-action-profile2.p4 ..... Passed    4.64 sec
2/1399 Test #4: dpdk/testdata/p4_l6_samples/psa-action-profile3.p4 ..... Passed    4.43 sec
3/1399 Test #2: dpdk/testdata/p4_l6_samples/psa-action-profile1.p4 ..... Passed    4.68 sec
  Start    5: dpdk/testdata/p4_l6_samples/psa-action-profile4.p4
  Start    6: dpdk/testdata/p4_l6_samples/psa-action-selector1.p4
  Start    7: dpdk/testdata/p4_l6_samples/psa-action-selector2.p4
4/1399 Test #5: dpdk/testdata/p4_l6_samples/psa-action-profile4.p4 ..... Passed    2.73 sec
  Start    8: dpdk/testdata/p4_l6_samples/psa-action-selector3.p4
5/1399 Test #7: dpdk/testdata/p4_l6_samples/psa-action-selector2.p4 ..... Passed    2.86 sec
6/1399 Test #6: dpdk/testdata/p4_l6_samples/psa-action-selector1.p4 ..... Passed    2.86 sec
  Start    9: dpdk/testdata/p4_l6_samples/psa-basic-counter-bmv2.p4
  Start   10: dpdk/testdata/p4_l6_samples/psa-counter1.p4
7/1399 Test #10: dpdk/testdata/p4_l6_samples/psa-counter1.p4 ..... Passed    2.40 sec
8/1399 Test #8: dpdk/testdata/p4_l6_samples/psa-action-selector3.p4 ..... Passed    2.76 sec
  Start   11: dpdk/testdata/p4_l6_samples/psa-counter2.p4
  Start   12: dpdk/testdata/p4_l6_samples/psa-counter3.p4

```

Importante:

O número de testes em cada versão do p4c não é exatamente o mesmo, sendo assim, isso não afeta o resultado do processo, o mesmo deverá passar de **100%**, caso ocorra, alguma falha ou erro, não prossiga para a próxima etapa.

```

  Start 1399: gtestp4c
1396/1399 Test #1396: p14_to_l6/testdata/p4_l4_samples/wide_action1.p4 ..... Passed    4.30 sec
1397/1399 Test #1397: p14_to_l6/testdata/p4_l4_samples/wide_action3.p4 ..... Passed    4.40 sec
1398/1399 Test #1399: gtestp4c ..... Passed   95.17 sec
1399/1399 Test #1398: p14_to_l6/testdata/p4_l4_samples/switch_20160512/switch.p4 ..... Passed  161.92 sec

```

25. Efetue a instalação com o comando a seguir, conforme a ilustração a seguir:

```
sudo make install
```

Importante:

A etapa 25 não deverá conter erros, caso gere algum, retorne as etapas anteriores ou consulte as fontes originais de onde foi retirado este tutorial que foi totalmente modificado para um ambiente físico.

```
root@feec:/home/p4/p4c/build# sudo make install
[ 0%] Built target update_includes
[ 0%] Built target linkgraphs
[ 0%] Built target linkp4cdpdk
[ 0%] Built target linkbmv2
[ 0%] Built target linkp4cebpf
[ 0%] Built target linkp4cubpf
[ 0%] Built target linkp4test
[ 1%] Built target p4c_driver
[ 3%] Built target p4ctoolkit
[ 10%] Built target irgenerator
[ 11%] Built target genIR
[ 13%] Built target ir
[ 13%] Built target mkP4configdir
[ 13%] Built target mkvldirs
[ 13%] Built target mkp4dirs
[ 35%] Built target frontend
[ 45%] Built target controlplane
[ 50%] Built target midend
[ 76%] Built target p4c-dpdk
[ 78%] Built target bmv2backend
[ 81%] Built target p4c-bm2-ss
[ 83%] Built target p4c-bm2-psa
[ 86%] Built target p4c-ebpf
[ 88%] Built target p4c-ubpf
[ 90%] Built target p4test
[ 92%] Built target p4c-graphs
[ 95%] Built target gtest
[100%] Built target gtestp4c
```

Install the project...

```
-- Install configuration: "DEBUG"
-- Installing: /usr/local/share/p4c/p4include
-- Installing: /usr/local/share/p4c/p4include/psa.p4
-- Installing: /usr/local/share/p4c/p4include/ubpf_model.p4
-- Installing: /usr/local/share/p4c/p4include/p4d2model.p4
-- Installing: /usr/local/share/p4c/p4include/core.p4
-- Installing: /usr/local/share/p4c/p4include/vlmodel.p4
-- Installing: /usr/local/share/p4c/p4include/ebpf_model.p4
-- Installing: /usr/local/share/p4c/p4include/xdp_model.p4
-- Installing: /usr/local/bin/p4c
-- Installing: /usr/local/share/p4c/p4c_src
-- Installing: /usr/local/share/p4c/p4c_src/util.py
-- Installing: /usr/local/share/p4c/p4c_src/main.py
-- Installing: /usr/local/share/p4c/p4c_src/driver.py
-- Installing: /usr/local/share/p4c/p4c_src/__init__.py
-- Installing: /usr/local/share/p4c/p4c_src/config.py
-- Installing: /usr/local/share/p4c/p4c_src/p4c.bmv2.cfg
-- Installing: /usr/local/share/p4c/p4c_src/p4c.ebpf.cfg
-- Installing: /usr/local/share/p4c/p4c_src/p4c.dpdk.cfg
-- Installing: /usr/local/bin/p4c-dpdk
-- Installing: /usr/local/bin/p4c-bm2-ss
-- Installing: /usr/local/bin/p4c-bm2-psa
-- Installing: /usr/local/bin/p4c-ebpf
-- Up-to-date: /usr/local/share/p4c/p4include
-- Up-to-date: /usr/local/share/p4c/p4include/ebpf_model.p4
-- Installing: /usr/local/bin/p4c-ubpf
-- Up-to-date: /usr/local/share/p4c/p4include
-- Up-to-date: /usr/local/share/p4c/p4include/ubpf_model.p4
-- Installing: /usr/local/bin/p4test
-- Installing: /usr/local/bin/p4c-graphs
root@feec:/home/p4/p4c/build#
```

26. Verificando a versão do p4c, e se nesta etapa tiver um retorno, semelhante a ilustração a seguir, a instalação foi p4c está concluída:

```
p4c -version
```

```
root@feec: /home/p4/p4c/build
root@feec:/home/p4/p4c/build# p4c --version
p4c 1.2.0+g202103291035~a69e52 (SHA: 2790e7bee BUILD: DEBUG)
root@feec:/home/p4/p4c/build#
```

27. Nesta etapa iremos baixar o bmv2, que é o modelo comportamental, chamado de módulo de chave bmv2 e denominado "bmv2"

```
cd /home && git clone git://github.com/p4lang/behavioral-model.git
```

28. Após a etapa anterior, iremos acessar o diretório do bmv2 e efetuar algumas instalações, conforme os comandos a seguir:

```
cd behavioral-model/ && ./install_deps.sh && ./autogen.sh
```


```
git checkout -b <new-branch-name>
HEAD is now at c7e718a Merge pull request #7 from bnewbold/patch-1
Collecting cffi
  Downloading https://files.pythonhosted.org/packages/2b/cf/9a3b04e57191a970836aeaa8b2075574f02fbd65d6368457a2f13213e7f/cffi-1.14.5-cp36-cp36m-manylinux1_x86_64.whl (409kB)
100% |#####| 409kB 2.3MB/s
Collecting pycparser (from cffi)
  Downloading https://files.pythonhosted.org/packages/ae/e7/d9c3a176ca4b02024debf82342dab36efadfc5776f9c8db077e8f6e71821/pycparser-2.20-py2.py3-none-any.whl (112kB)
100% |#####| 112kB 5.2MB/s
Installing collected packages: pycparser, cffi
Successfully installed cffi-1.14.5 pycparser-2.20
Processing /home/behavioral-model/tmp.hVlY6EgwOt/nnpy
Requirement already satisfied: cffi in /usr/local/lib/python3.6/dist-packages (from nnpy==0.1)
Requirement already satisfied: pycparser in /usr/local/lib/python3.6/dist-packages (from cffi->nnpy==0.1)
Installing collected packages: nnpy
Running setup.py install for nnpy ... done
Successfully installed nnpy-0.1
root@feec:/home/behavioral-model#
```

```
root@feec:/home/behavioral-model# ./autogen.sh
libtoolize: putting auxiliary files in '.'.
libtoolize: copying file './ltmain.sh'
libtoolize: putting macros in AC_CONFIG_MACRO_DIRS, 'm4'.
libtoolize: copying file 'm4/libtool.m4'
libtoolize: copying file 'm4/ltoptions.m4'
libtoolize: copying file 'm4/ltugar.m4'
libtoolize: copying file 'm4/ltversion.m4'
libtoolize: copying file 'm4/lt~obsolete.m4'
configure.ac:124: installing './compile'
configure.ac:125: installing './config.guess'
configure.ac:125: installing './config.sub'
configure.ac:7: installing './install-sh'
configure.ac:7: installing './missing'
PI/Makefile.am: installing './depcomp'
pdfixed/Makefile.am:12: installing './py-compile'
parallel-tests: installing './test-driver'
root@feec:/home/behavioral-model#
```

Resultados da etapa 28°

29. Ainda dentro do diretório: /home/behavioral-model, execute os comandos a seguir:

```
./configure && make
```

 root@feec: /home/behavioral-model

```
config.status: creating third_party/spdlog/Makefile
config.status: creating include/Makefile
config.status: creating src/Makefile
config.status: creating src/bf_lpm_trie/Makefile
config.status: creating src/bm_sim/Makefile
config.status: creating src/bm_runtime/Makefile
config.status: creating src/BMI/Makefile
config.status: creating src/bm_apps/Makefile
config.status: creating src/bm_apps/examples/Makefile
config.status: creating targets/Makefile
config.status: creating targets/simple_router/Makefile
config.status: creating targets/l2_switch/Makefile
config.status: creating targets/l2_switch/learn_client/Makefile
config.status: creating targets/simple_switch/Makefile
config.status: creating targets/simple_switch/tests/Makefile
config.status: creating targets/simple_switch/tests/CLI_tests/Makefile
config.status: creating targets/psa_switch/Makefile
config.status: creating targets/psa_switch/tests/Makefile
config.status: creating tests/Makefile
config.status: creating tests/stress_tests/Makefile
config.status: creating tools/Makefile
config.status: creating pdfixed/Makefile
config.status: creating pdfixed/include/Makefile
config.status: creating PI/Makefile
config.status: creating tests/utils.cpp
config.status: creating src/bm_sim/version.cpp
config.status: creating mininet/stress_test_ipv4.py
config.status: creating targets/simple_switch/tests/CLI_tests/run_one_test.py
config.status: creating config.h
config.status: executing depfiles commands
config.status: executing libtool commands
config.status: executing include/bm/config.h commands
config.status: creating include/bm/config.h - prefix BM for config.h defines

Features recap .....
Coverage enabled ..... : no
Logging macros enabled ..... : yes
With Nanomsg ..... : yes
Event logger enabled ..... : yes
Debugger enabled ..... : no
With Thrift ..... : yes
With pdfixed ..... : no
With PI ..... : no
root@feec:/home/behavioral-model#
```



```

root@feec:/home/behavioral-model
libtool: link: g++ -Wall -Wextra -pthread -g -O2 -o .libs/psa_switch main.o ../../src/bm_runtime/.libs/libbmruntime.a ../../thrift/src/.libs/libruntimestubs.so ../../libs/libpsaswitch.a -lboost_system -lthrift -lboost_program_options -lboost_filesystem ../../libs/libpsaswitch_thrift.so -lboost_thread -ldl -lpcap -lgmp -lJudy -lnanomsg -pthread
rm -f psa_switch CLI psa_switch CLI.tmp
sed -e 's|@pythondir[@]|/usr/local/lib/python3.6/site-packages|g' ./psa_switch_CLI.in >psa_switch_CLI.tmp
chmod +x psa_switch_CLI.tmp
chmod a-w psa_switch_CLI.tmp
mv psa_switch_CLI.tmp psa_switch_CLI
make[5]: Leaving directory '/home/behavioral-model/targets/psa_switch'
Making all in tests
make[5]: Entering directory '/home/behavioral-model/targets/psa_switch/tests'
Making all in .
make[6]: Entering directory '/home/behavioral-model/targets/psa_switch/tests'
make[6]: Nothing to be done for 'all-am'.
make[6]: Leaving directory '/home/behavioral-model/targets/psa_switch/tests'
make[5]: Leaving directory '/home/behavioral-model/targets/psa_switch/tests'
make[4]: Leaving directory '/home/behavioral-model/targets/psa_switch'
make[3]: Leaving directory '/home/behavioral-model/targets/psa_switch'
make[3]: Entering directory '/home/behavioral-model/targets'
make[3]: Nothing to be done for 'all-am'.
make[3]: Leaving directory '/home/behavioral-model/targets'
make[2]: Leaving directory '/home/behavioral-model/targets'
Making all in tools
make[2]: Entering directory '/home/behavioral-model/tools'
rm -f bm_CLI bm_CLI.tmp
sed -e 's|@pythondir[@]|/usr/local/lib/python3.6/site-packages|g' ./bm_CLI.in >bm_CLI.tmp
chmod +x bm_CLI.tmp
chmod a-w bm_CLI.tmp
mv bm_CLI.tmp bm_CLI
rm -f bm_p4dbg bm_p4dbg.tmp
sed -e 's|@pythondir[@]|/usr/local/lib/python3.6/site-packages|g' ./bm_p4dbg.in >bm_p4dbg.tmp
chmod +x bm_p4dbg.tmp
chmod a-w bm_p4dbg.tmp
mv bm_p4dbg.tmp bm_p4dbg
rm -f bm_nanomsg_events bm_nanomsg_events.tmp
sed -e 's|@pythondir[@]|/usr/local/lib/python3.6/site-packages|g' ./bm_nanomsg_events.in >bm_nanomsg_events.tmp
chmod +x bm_nanomsg_events.tmp
chmod a-w bm_nanomsg_events.tmp
mv bm_nanomsg_events.tmp bm_nanomsg_events
make[2]: Leaving directory '/home/behavioral-model/tools'
make[2]: Entering directory '/home/behavioral-model'
make[2]: Leaving directory '/home/behavioral-model'
make[1]: Leaving directory '/home/behavioral-model'
root@feec:/home/behavioral-model#

```

Resultado da etapa 29°

30. Ainda dentro do diretório: /home/behavioral-model, execute o comando seguir:

`sudo make install -j4`

```

root@feec:/home/behavioral-model
Byte-compiling python modules (optimized versions) ...
pswitch_CLI.py
libtool: install: /usr/bin/install -c .libs/psa_switch /usr/local/bin/psa_switch
make[5]: Leaving directory '/home/behavioral-model/targets/psa_switch'
make[4]: Leaving directory '/home/behavioral-model/targets/psa_switch'
Making install in tests
make[4]: Entering directory '/home/behavioral-model/targets/psa_switch/tests'
Making install in .
make[5]: Entering directory '/home/behavioral-model/targets/psa_switch/tests'
make[6]: Entering directory '/home/behavioral-model/targets/psa_switch/tests'
make[6]: Nothing to be done for 'install-exec-am'.
make[6]: Nothing to be done for 'install-data-am'.
make[6]: Leaving directory '/home/behavioral-model/targets/psa_switch/tests'
make[5]: Leaving directory '/home/behavioral-model/targets/psa_switch/tests'
make[4]: Leaving directory '/home/behavioral-model/targets/psa_switch/tests'
make[3]: Leaving directory '/home/behavioral-model/targets/psa_switch'
make[2]: Leaving directory '/home/behavioral-model/targets/psa_switch'
make[2]: Entering directory '/home/behavioral-model/targets'
make[3]: Entering directory '/home/behavioral-model/targets'
make[3]: Nothing to be done for 'install-exec-am'.
make[3]: Nothing to be done for 'install-data-am'.
make[3]: Leaving directory '/home/behavioral-model/targets'
make[2]: Leaving directory '/home/behavioral-model/targets'
make[1]: Leaving directory '/home/behavioral-model/targets'
Making install in tools
make[1]: Entering directory '/home/behavioral-model/tools'
make[2]: Entering directory '/home/behavioral-model/tools'
/bin/mkdir -p '/usr/local/bin'
/bin/mkdir -p '/usr/local/lib/python3.6/site-packages'
/usr/bin/install -c bm_CLI bm_p4dbg bm_nanomsg_events '/usr/local/bin'
/usr/bin/install -c -m 644 bmpy_utils.py runtime_CLI.py p4dbg.py nanomsg_client.py '/usr/local/lib/python3.6/site-packages'
Byte-compiling python modules...
bmpy_utils.py runtime_CLI.py p4dbg.py nanomsg_client.py
Byte-compiling python modules (optimized versions) ...
bmpy_utils.py runtime_CLI.py p4dbg.py nanomsg_client.py
make[2]: Leaving directory '/home/behavioral-model/tools'
make[1]: Leaving directory '/home/behavioral-model/tools'
make[1]: Entering directory '/home/behavioral-model'
make[2]: Entering directory '/home/behavioral-model'
make[2]: Nothing to be done for 'install-exec-am'.
make[2]: Nothing to be done for 'install-data-am'.
make[2]: Leaving directory '/home/behavioral-model'
make[1]: Leaving directory '/home/behavioral-model'
root@feec:/home/behavioral-model#

```

Resultado da etapa 30°

31. Nesta etapa, será efetuado um teste de unidade do **bmvs2**, que deve ser executado após a instalação data etapa **30º** ser concluída, caso contrário, erros serão retornados, execute o comando a seguir:

```
make check -j4
```

```
PASS: test_truncate
PASS: test_swap
PASS: test_recirc
PASS: test_parser_error
PASS: test_packet_redirect
PASS: test_queueing

=====
Testsuite summary for bm 1.14.0-27c23594
=====
# TOTAL: 6
# PASS: 6
# SKIP: 0
# XFAIL: 0
# FAIL: 0
# XPASS: 0
# ERROR: 0
```

```
make[5]: Leaving directory '/home/behavioral-model/targets/simple_switch/tests/CLI_tests'
make[4]: Leaving directory '/home/behavioral-model/targets/simple_switch/tests'
make[3]: Leaving directory '/home/behavioral-model/targets/simple_switch'
make[2]: Leaving directory '/home/behavioral-model/targets/simple_switch'
Making check in psa_switch
make[2]: Entering directory '/home/behavioral-model/targets/psa_switch'
make check-recursive
make[3]: Entering directory '/home/behavioral-model/targets/psa_switch'
Making check in .
make[4]: Entering directory '/home/behavioral-model/targets/psa_switch'
make[4]: Nothing to be done for 'check-am'.
make[4]: Leaving directory '/home/behavioral-model/targets/psa_switch'
Making check in tests
make[4]: Entering directory '/home/behavioral-model/targets/psa_switch/tests'
Making check in .
make[5]: Entering directory '/home/behavioral-model/targets/psa_switch/tests'
make test_all
make[6]: Entering directory '/home/behavioral-model/targets/psa_switch/tests'
debase='echo main.o | sed 's|^[^/]${}/deps&;s|.o$||'';\
g++ -DHAVE_CONFIG_H -I. -I../.. -I./../../include -I./../../third_party/jsoncpp/include -isystem ../../../../third_party/gtest/include -I../.. -I../DTESTDATADIR=\"./testdata\" -Wall -Wextra -pthread -g -O2 -MT main.o -MD -MP -MF $debase.Tpo -c -o main.o main.cpp &&\
mv -f $debase.Tpo $debase.Po
/bin/bash ../.././libtool --tag=CXX --mode=link g++ -Wall -Wextra -pthread -g -O2 -o test_all main.o ../../libsaswitch.la ../../../../third_party/gtest/libgtest.la ..
../../../../src/bm_apps/libbmapps.la -lboost_filesystem -lboost_thread -ldl -lpcap -lgmp -ljudy -lnanomsg
libtool: link: g++ -Wall -Wextra -pthread -g -O2 -o ./libs/test_all main.o ../../libs/libsaswitch.a -lboost_system -lboost_program_options ../../../../third_party/gtest/
libs/libgtest.a ../../../../src/bm_apps/.libs/libbmapps.a /home/behavioral-model/thrift_src/.libs/libruntimestubs.so -lthrift -lboost_filesystem -lboost_thread -ldl -lpca
-lgmp -ljudy -lnanomsg -pthread
make[6]: Leaving directory '/home/behavioral-model/targets/psa_switch/tests'
make[5]: Leaving directory '/home/behavioral-model/targets/psa_switch/tests'
make[4]: Leaving directory '/home/behavioral-model/targets/psa_switch/tests'
make[3]: Leaving directory '/home/behavioral-model/targets/psa_switch'
make[2]: Leaving directory '/home/behavioral-model/targets'
make[2]: Entering directory '/home/behavioral-model/targets'
make[2]: Nothing to be done for 'check-am'.
make[2]: Leaving directory '/home/behavioral-model/targets'
make[1]: Leaving directory '/home/behavioral-model/targets'
Making check in tools
make[1]: Entering directory '/home/behavioral-model/tools'
make[1]: Nothing to be done for 'check'.
make[1]: Leaving directory '/home/behavioral-model/tools'
make[1]: Entering directory '/home/behavioral-model'
make[1]: Leaving directory '/home/behavioral-model'
root@fec:/home/behavioral-model#
```

Resultados da etapa 31°

Importante:

A saída do make check é muito importante e deve ser executada, onde todos os módulos devem ser APROVADOS, se isso ocorrer, siga para a próxima etapa, caso contrário, ocorrerão erros inesperados.

- 32.** Nesta etapa final, iremos verificar se tivemos êxito em todo o processo, para isso, execute o comando a seguir:

```
cat VERSION
```

```
root@feec: /home/behavioral-model
root@feec:/home/behavioral-model# cat VERSION
1.14.0root@feec:/home/behavioral-model#
```

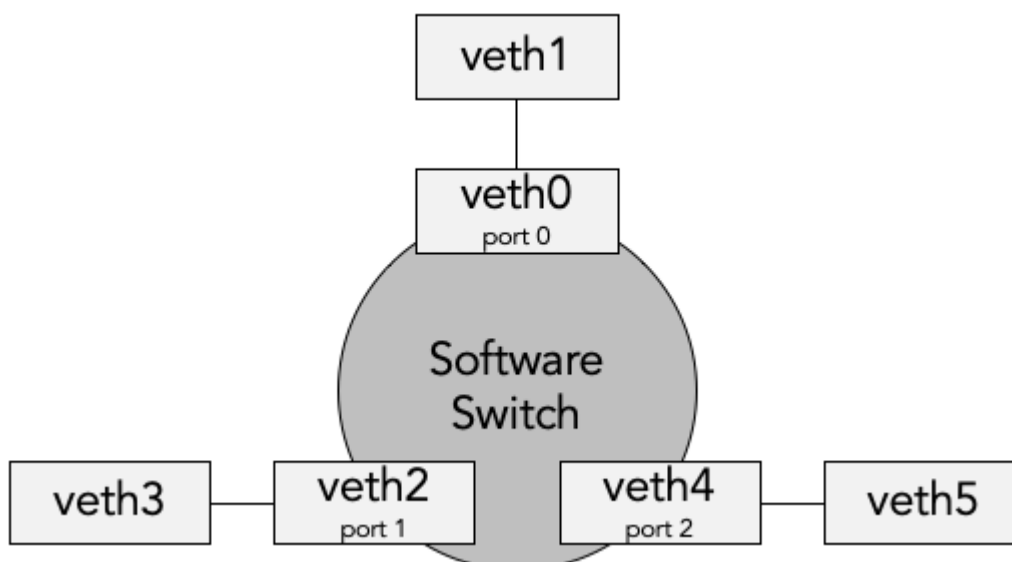
Resultado da etapa 32°

Efetuando testes pós instalado do Compilador P4

Objetivo:

Criar um programa P4 que processará apenas pacotes IPv4 sobre o protocolo Ethernet que conterà apenas uma única tabela, que deverá fazer uma pesquisa de correspondência de prefixo mais longa no endereço IP de destino, para decidir a porta de saída, este é o objetivo do ambiente pós-instalação do compilador P4.

Topologia do ambiente de testes com P4:



1. Execute do comando **ldconfig** que será necessário para fazer o cache necessário para as bibliotecas compartilhadas mais recentes encontradas nos diretórios especificados na linha de comando, execute o comando a seguir:

```
sudo ldconfig
```

2. Crie um diretório chamado `projetos_p4` dentro de `/home`, conforme o comando a seguir:

```
mkdir -p /home/projetos_p4
```

3. Acesse o diretório criado na etapa 2, e com um editor de texto de sua escolha, crie um arquivo chamado `p1.p4` com o conteúdo a seguir:

```
cd /home/projetos_p4 && vim p1.p4
```

```
#include <core.p4>
```

```
#include <vlmodel.p4>
```

```
typedef bit<48> EthernetAddress;
```

```
typedef bit<32> IPv4Address;
```

```
header ethernet_t {
```

```
    EthernetAddress dst_addr;
```

```
    EthernetAddress src_addr;
```

```
    bit<16>          ether_type;
```

```
}
```

```
header ipv4_t {
```

```
    bit<4>          version;
```

```
    bit<4>          ihl;
```

```
    bit<8>          diffserv;
```

```
    bit<16>         total_len;
```

```
    bit<16>         identification;
```

```
    bit<3>          flags;
```

```
    bit<13>         frag_offset;
```

```
    bit<8>          ttl;
```

```
    bit<8>          protocol;
```

```
    bit<16>         hdr_checksum;
```

```
    IPv4Address src_addr;
```

```

    IPv4Address dst_addr;
}

struct headers_t {
    ethernet_t ethernet;
    ipv4_t     ipv4;
}

struct metadata_t {
}

error {
    IPv4IncorrectVersion,
    IPv4OptionsNotSupported
}

parser my_parser(packet_in packet,
                  out headers_t hd,
                  inout metadata_t meta,
                  inout standard_metadata_t standard_meta)
{
    state start {
        packet.extract(hd.ethernet);
        transition select(hd.ethernet.ether_type) {
            0x0800: parse_ipv4;
            default: accept;
        }
    }

    state parse_ipv4 {
        packet.extract(hd.ipv4);
        verify(hd.ipv4.version == 4w4, error.IPv4IncorrectVersion);
        verify(hd.ipv4.ihl == 4w5, error.IPv4OptionsNotSupported);
        transition accept;
    }
}

control my_deparser(packet_out packet,
                    in headers_t hdr)
{

```

```

    apply {
        packet.emit(hdr.ethernet);
        packet.emit(hdr.ipv4);
    }
}

control my_verify_checksum(inout headers_t hdr,
                           inout metadata_t meta)
{
    apply { }
}

control my_compute_checksum(inout headers_t hdr,
                            inout metadata_t meta)
{
    apply { }
}

control my_ingress(inout headers_t hdr,
                   inout metadata_t meta,
                   inout standard_metadata_t standard_metadata)
{
    bool dropped = false;

    action drop_action() {
        mark_to_drop(standard_metadata);
        dropped = true;
    }

    action to_port_action(bit<9> port) {
        hdr.ipv4.ttl = hdr.ipv4.ttl - 1;
        standard_metadata.egress_spec = port;
    }

    table ipv4_match {
        key = {
            hdr.ipv4.dst_addr: lpm;
        }
        actions = {
            drop_action;

```

```

        to_port_action;
    }
    size = 1024;
    default_action = drop_action;
}

apply {
    ipv4_match.apply();
    if (dropped) return;
}
}

control my_egress(inout headers_t hdr,
                  inout metadata_t meta,
                  inout standard_metadata_t standard_metadata)
{
    apply { }
}

V1Switch(my_parser(),
         my_verify_checksum(),
         my_ingress(),
         my_egress(),
         my_compute_checksum(),
         my_deparser()) main;

```

Importante:

Este é um programa possui uma única tabela de pesquisa, que faz uma correspondência de prefixo mais longa (LPF) no endereço IP de destino no pacote recebido. A ação é descartar o pacote ou encaminhá-lo para uma porta de saída específica.

4. Efetue a compilação o programa P4, utilizando a opção -b opção, que seleciona bmv2 (**Behavioral Model Version 2**) como target, que é a chave de software que usaremos para executar o programa P4 e depois iremos listar o resultado com o comando: `ls -lha`

```
p4c -b bmv2 p1.p4 -o p1.bmv2
```



```

root@feec:/home/projetos_p4# p4c -b bmv2 pl.p4 -o pl.bmv2
root@feec:/home/projetos_p4# ls -lha
total 16K
drwxr-xr-x 3 root root 4,0K abr 21 22:20 .
drwxr-xr-x 8 root root 4,0K abr 21 22:13 ..
drwxr-xr-x 2 root root 4,0K abr 21 22:20 pl.bmv2
-rw-r--r-- 1 root root 2,7K abr 21 22:16 pl.p4
root@feec:/home/projetos_p4# █

```

Resultado da etapa 4º

5. Nesta etapa, iremos criar interfaces Ethernet virtuais, que será dividida em três pares de interfaces virtuais Ethernet (veth):

Uma veth interface é uma interface Ethernet virtual (ou seja, falsa), na qual um aplicativo (o switch de software em nosso caso), poderá enviar e receber pacotes Ethernet da mesma forma que uma interface Ethernet real.

Caso ocorra um problema de uma interface veth, onde os pacotes não saiam de uma porta Ethernet real. Em vez disso, as veth interfaces são sempre criadas em pares, conforme o exemplo abaixo:

veth0-veth1, veth2-veth3, e veth4-veth5

Quando o aplicativo envia o pacote em uma interface veth, ele chega na outra veth interface do par.

Durante a criação dos três pares de interfaces Ethernet virtuais, definimos a unidade de transferência de mensagens (MTU) de cada interface para **9500**, para permitir enviar e receber pacotes nessa unidade máxima. E desabilitamos o IPv6 em cada interface para impedir que o kernel envie solicitações de roteador e relatórios de escuta de multicast (isso não impede que o switch de software envie pacotes IPv6 pela interface).

Importante:

Os comandos serão executados LINHA a LINHA, ou o usuário poderá criar um script para agilizar o processo, conforme queira.

Primeiro par: veth0-veth1

```

sudo ip link add name veth0 type veth peer name veth1
sudo ip link set dev veth0 up
sudo ip link set dev veth1 up
sudo ip link set veth0 mtu 9500
sudo ip link set veth1 mtu 9500
sudo sysctl net.ipv6.conf.veth0.disable_ipv6=1
sudo sysctl net.ipv6.conf.veth1.disable_ipv6=1


```

Segundo par: veth2-veth3

```
sudo ip link add name veth2 type veth peer name veth3
sudo ip link set dev veth2 up
sudo ip link set dev veth3 up
sudo ip link set veth2 mtu 9500
sudo ip link set veth3 mtu 9500
sudo sysctl net.ipv6.conf.veth2.disable_ipv6=1
sudo sysctl net.ipv6.conf.veth3.disable_ipv6=1
```

Terceiro par: veth4-veth5

```
sudo ip link add name veth4 type veth peer name veth5
sudo ip link set dev veth4 up
sudo ip link set dev veth5 up
sudo ip link set veth4 mtu 9500
sudo ip link set veth5 mtu 9500
sudo sysctl net.ipv6.conf.veth4.disable_ipv6=1
sudo sysctl net.ipv6.conf.veth5.disable_ipv6=1
```

 root@feec: /home/projetos_p4

```
root@feec:/home/projetos_p4# sudo ip link add name veth0 type veth peer name veth1
root@feec:/home/projetos_p4# sudo ip link set dev veth0 up
root@feec:/home/projetos_p4# sudo ip link set dev veth1 up
root@feec:/home/projetos_p4# sudo ip link set veth0 mtu 9500
root@feec:/home/projetos_p4# sudo ip link set veth1 mtu 9500
root@feec:/home/projetos_p4# sudo sysctl net.ipv6.conf.veth0.disable_ipv6=1
net.ipv6.conf.veth0.disable_ipv6 = 1
root@feec:/home/projetos_p4# sudo sysctl net.ipv6.conf.veth1.disable_ipv6=1
net.ipv6.conf.veth1.disable_ipv6 = 1
root@feec:/home/projetos_p4#
root@feec:/home/projetos_p4#
root@feec:/home/projetos_p4# sudo ip link add name veth2 type veth peer name veth3
root@feec:/home/projetos_p4# sudo ip link set dev veth2 up
root@feec:/home/projetos_p4# sudo ip link set dev veth3 up
root@feec:/home/projetos_p4# sudo ip link set veth2 mtu 9500
root@feec:/home/projetos_p4# sudo ip link set veth3 mtu 9500
root@feec:/home/projetos_p4# sudo sysctl net.ipv6.conf.veth2.disable_ipv6=1
net.ipv6.conf.veth2.disable_ipv6 = 1
root@feec:/home/projetos_p4# sudo sysctl net.ipv6.conf.veth3.disable_ipv6=1
net.ipv6.conf.veth3.disable_ipv6 = 1
root@feec:/home/projetos_p4#
root@feec:/home/projetos_p4#
root@feec:/home/projetos_p4# sudo ip link add name veth4 type veth peer name veth5
root@feec:/home/projetos_p4# sudo ip link set dev veth4 up
root@feec:/home/projetos_p4# sudo ip link set dev veth5 up
root@feec:/home/projetos_p4# sudo ip link set veth4 mtu 9500
root@feec:/home/projetos_p4# sudo ip link set veth5 mtu 9500
root@feec:/home/projetos_p4# sudo sysctl net.ipv6.conf.veth4.disable_ipv6=1
net.ipv6.conf.veth4.disable_ipv6 = 1
root@feec:/home/projetos_p4# sudo sysctl net.ipv6.conf.veth5.disable_ipv6=1
net.ipv6.conf.veth5.disable_ipv6 = 1
root@feec:/home/projetos_p4# █
```

Resultado da etapa 5°

6. Nesta próxima etapa, abriremos várias sessões SSH, primeira sessão iniciaremos a troca de software como um processo em segundo plano:

```
sudo simple_switch --interface 0@veth0 --interface 1@veth2 --interface 2@veth4 pl.bmv2/pl.json &
```

```
root@feec: /home/projetos_p4
root@feec:/home/projetos_p4# sudo simple_switch --interface 0@veth0 --interface 1@veth2 --interface 2@veth4 pl.bmv2/pl.json &
[1] 13428
root@feec:/home/projetos_p4# Calling target program-options parser
Adding interface veth0 as port 0
Adding interface veth2 as port 1
Adding interface veth4 as port 2
```

7. Aguarde o processamento e nesta mesma sessão SSH, inicie a Interface de linha de comando (CLI) para a troca de software, com o comando:

`simple_switch_CLI`

```
root@feec: /home/projetos_p4
root@feec:/home/projetos_p4# sudo simple_switch --interface 0@veth0 --interface 1@veth2 --interface 2@veth4 pl.bmv2/pl.json &
[1] 13428
root@feec:/home/projetos_p4# Calling target program-options parser
Adding interface veth0 as port 0
Adding interface veth2 as port 1
Adding interface veth4 as port 2
root@feec:/home/projetos_p4# simple_switch_CLI
Obtaining JSON from switch...
Done
Control utility for runtime P4 table manipulation
RuntimeCmd: █
```

8. Na CLI, execute o comando `help` e configura o resultado: **help**

```
RuntimeCmd: help

Documented commands (type help <topic>):
=====
act_prof_add_member_to_group      reset_state
act_prof_create_group             serialize_state
act_prof_create_member            set_crc16_parameters
act_prof_delete_group             set_crc32_parameters
act_prof_delete_member            set_queue_depth
act_prof_dump                     set_queue_rate
act_prof_dump_group               shell
act_prof_dump_member              show_actions
act_prof_modify_member             show_ports
act_prof_remove_member_from_group show_pvs
counter_read                       show_tables
counter_reset                     swap_configs
counter_write                     switch_info
get_time_elapsed                  table_add
get_time_since_epoch              table_clear
help                               table_delete
load_new_config_file              table_dump
mc_dump                            table_dump_entry
mc_mgrp_create                    table_dump_entry_from_key
mc_mgrp_destroy                   table_dump_group
mc_node_associate                 table_dump_member
mc_node_create                    table_indirect_add
mc_node_destroy                   table_indirect_add_member_to_group
mc_node_dissociate                table_indirect_add_with_group
mc_node_update                    table_indirect_create_group
mc_set_lag_membership             table_indirect_create_member
meter_array_set_rates             table_indirect_delete
meter_get_rates                   table_indirect_delete_group
meter_set_rates                   table_indirect_delete_member
mirroring_add                     table_indirect_modify_member
mirroring_add_mc                  table_indirect_remove_member_from_group
mirroring_delete                  table_indirect_reset_default
mirroring_get                     table_indirect_set_default
port_add                          table_indirect_set_default_with_group
port_remove                       table_info
pvs_add                           table_modify
pvs_clear                         table_num_entries
pvs_get                           table_reset_default
```

```

pvs_remove
register_read
register_reset
register_write
table_set_default
table_set_timeout
table_show_actions
write_config_to_file

Undocumented commands:
=====
EOF greet

RuntimeCmd: █

```

9. Execute o comando `show_tables`, que informa se uma `my_ingress.ipv4_match` consta em uma tabela:

```
show_tables
```

```

root@feec: /home/projetos_p4
RuntimeCmd: show_tables
my_ingress.ipv4_match      [implementation=None, mk=ipv4.dst_addr(lpm, 32)]
tbl_pll187                 [implementation=None, mk=]
RuntimeCmd: █

```

10. Execute o comando `table_info`, que exibe informação de uma tabela:

```
table_info ipv4_match
```

```

RuntimeCmd: table_info ipv4_match
my_ingress.ipv4_match      [implementation=None, mk=ipv4.dst_addr(lpm, 32)]
*****
my_ingress.drop_action     []
my_ingress.to_port_action  [port(9)]
RuntimeCmd: █

```

11. Adicionando rotas à tabela de rotas no switch de software CLI, será utilizado o `table_add`, comando para adicionar quatro rotas à tabela de rotas:

- Todo o tráfego para o prefixo `10.10.0.0/16` é enviado para a porta 0
- Todo o tráfego para o prefixo `11.11.0.0/16` é enviado para a porta 1
- Todo o tráfego para o prefixo `12.12.0.0/16` é enviado para a porta 2
- Todo o tráfego para o prefixo `20.20.20.0/24` é descartado.
- Todo o tráfego que não corresponde a nenhum dos prefixos acima também é descartado porque a ação padrão para a tabela é descartar.

Observação: Execute os comandos LINHA a LINHA no CLI do switch:

```
table_add ipv4_match to_port_action 11.11.0.0/16 => 1
```

```
table_add ipv4_match to_port_action 12.12.0.0/16 => 2
```

```
table_add ipv4_match drop_action 20.20.20.0/24 =>
```

```
root@feec: /home/projetos_p4
RuntimeCmd: table_add ipv4_match to_port_action 10.10.0.0/16 => 0
Adding entry to lpm match table ipv4_match
match key:          LPM-0a:0a:00:00/16
action:             to_port_action
runtime data:       00:00
Entry has been added with handle 0
RuntimeCmd: table_add ipv4_match to_port_action 11.11.0.0/16 => 1
Adding entry to lpm match table ipv4_match
match key:          LPM-0b:0b:00:00/16
action:             to_port_action
runtime data:       00:01
Entry has been added with handle 1
RuntimeCmd: table_add ipv4_match to_port_action 12.12.0.0/16 => 2
Adding entry to lpm match table ipv4_match
match key:          LPM-0c:0c:00:00/16
action:             to_port_action
runtime data:       00:02
Entry has been added with handle 2
RuntimeCmd: table_add ipv4_match drop_action 20.20.20.0/24 =>
Adding entry to lpm match table ipv4_match
match key:          LPM-14:14:14:00/24
action:             drop_action
runtime data:
Entry has been added with handle 3
RuntimeCmd: █
```

Resultado da etapa 11°

12. Executando o comando `table_dump`, que mostra as entradas que adicionamos à tabela:

```
table_dump ipv4_match
```

Importante:

Repare que todo o procedimento está sendo feito no diretório que criamos anteriormente: `/home/projetos_p4`

```

root@feec: /home/projetos_p4
RuntimeCmd: table_dump ipv4_match
=====
TABLE ENTRIES
*****
Dumping entry 0x0
Match key:
* ipv4.dst_addr      : LPM      0a0a0000/16
Action entry: my_ingress.to_port_action - 00
*****
Dumping entry 0x1
Match key:
* ipv4.dst_addr      : LPM      0b0b0000/16
Action entry: my_ingress.to_port_action - 01
*****
Dumping entry 0x2
Match key:
* ipv4.dst_addr      : LPM      0c0c0000/16
Action entry: my_ingress.to_port_action - 02
*****
Dumping entry 0x3
Match key:
* ipv4.dst_addr      : LPM      14141400/24
Action entry: my_ingress.drop_action -
=====
Dumping default entry
Action entry: my_ingress.drop_action -
=====
RuntimeCmd: █

```

Resultado da etapa 12°

13. Em outra sessa SSH, iremos executar o comando para descarregar pacotes que chegam na interface veth1:

```
sudo tcpdump -n -i veth3
```

```

root@feec: /home/projetos_p4
root@feec:/home/projetos_p4# sudo tcpdump -n -i veth3
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on veth3, link-type EN10MB (Ethernet), capture size 262144 bytes
█

```

Resultado da etapa 13°

14. Nesta próxima etapa iremos injetar alguns pacotes no switch de software, em outra sessão SSH separada, inicie o software scapy, que usaremos para injetar pacotes no switch de software:

```
sudo scapy
```



```
root@feec: ~
root@feec:~# sudo scapy
INFO: Can't import matplotlib. Won't be able to plot.
INFO: Can't import PyX. Won't be able to use psdump() or pdfdump().
INFO: Can't import python ecdsa lib. Disabled certificate manipulation tools
Welcome to Scapy (2.3.3)
>>> p = Ether()/IP(dst="11.11.1.1")/UDP()
>>> sendp(p, iface="veth1")
.
Sent 1 packets.
>>> p = Ether()/IP(dst="12.12.1.1")/UDP()
>>> sendp(p, iface="veth1")
.
Sent 1 packets.
>>> █
```

Resultado da etapa 14°

Importante:

Se chegou até a etapa **14º**, meus parabéns! Deu tudo certo. O tempo gasto para este procedimento varia muito do hardware onde o ambiente será executado, em nossa máquina física, que citamos suas configurações no início de tutorial levou mais de 5h, conforme o uptime do software htop, na imagem a seguir:

```
root@feec: /home/p4/p4c
1 [ 0.0%] Tasks: 94, 198 thr: 1 running
2 [ 0.0%] Load average: 0.00 0.02 0.00
3 [ 0.7%] Uptime: 05:36:20
4 [ 0.0%]
Mem[|||||] 508M/5.68G
Swp[|] 780K/5.86G

PID USER PRI NI VIRT RES SHR S CPU% MEM% TIME+ Command
16714 root 20 0 27504 4860 3520 R 0.7 0.1 1:34.89 htop
13433 root 20 0 679M 21476 20132 S 0.0 0.4 0:00.80 simple_switch --interface 0@veth0 --interface 1@veth2 --interface 2@veth4 pl.bmv2/pl.json
792 messagebu 20 0 51332 4356 2776 S 0.0 0.1 0:00.59 /usr/bin/dbus-daemon --system --address=systemd: --nofork --nopidfile --systemd-activation --syslog-only
881 avahi 20 0 47264 2424 2084 S 0.0 0.0 0:00.10 avahi-daemon: running [feec.local]
13429 root 20 0 679M 21476 20132 S 0.0 0.4 0:01.25 simple_switch --interface 0@veth0 --interface 1@veth2 --interface 2@veth4 pl.bmv2/pl.json
1333 gdm 20 0 1007M 13612 5556 S 0.0 0.2 0:01.28 /usr/lib/gnome-settings-daemon/gsd-color
1228 gdm 20 0 3816M 125M 70368 S 0.0 2.2 0:10.54 /usr/bin/gnome-shell
13434 root 20 0 679M 21476 20132 S 0.0 0.4 0:00.38 simple_switch --interface 0@veth0 --interface 1@veth2 --interface 2@veth4 pl.bmv2/pl.json
11516 root 20 0 101M 4184 3100 S 0.0 0.1 0:01.41 sshd: root@pts/1
791 root 20 0 491M 6656 4136 S 0.0 0.1 0:01.36 /usr/lib/udisks2/udisksd
13431 root 20 0 679M 21476 20132 S 0.0 0.4 0:00.03 simple_switch --interface 0@veth0 --interface 1@veth2 --interface 2@veth4 pl.bmv2/pl.json
926 root 20 0 175M 4388 3592 S 0.0 0.1 0:00.62 /usr/sbin/thermald --no-daemon --dbus-enable
1297 gdm 20 0 3816M 125M 70368 S 0.0 2.2 0:00.09 /usr/bin/gnome-shell
884 root 20 0 1047M 14400 4084 S 0.0 0.2 0:01.95 /usr/lib/snapd/snapd
13360 root 20 0 101M 7132 6140 S 0.0 0.1 0:00.03 sshd: [accepted]
829 root 20 0 175M 4388 3592 S 0.0 0.1 0:00.63 /usr/sbin/thermald --no-daemon --dbus-enable
920 root 20 0 286M 6836 4092 S 0.0 0.1 0:00.28 /usr/lib/policykit-1/polkitd --no-debug
830 root 20 0 281M 4840 3840 S 0.0 0.1 0:00.31 /usr/lib/accounts-service/accounts-daemon
1293 gdm 20 0 3816M 125M 70368 S 0.0 2.2 0:00.09 /usr/bin/gnome-shell
1288 rtkit 20 0 179M 2460 2196 S 0.0 0.0 0:00.07 /usr/lib/rtkit/rtkit-daemon
1076 root 20 0 1047M 14400 4084 S 0.0 0.2 0:00.04 /usr/lib/snapd/snapd
1287 rtkit 21 1 179M 2460 2196 S 0.0 0.0 0:00.14 /usr/lib/rtkit/rtkit-daemon
1071 kernoops 20 0 56948 416 0 S 0.0 0.0 0:00.15 /usr/sbin/kerneloops
13446 root 20 0 53656 18152 8072 S 0.0 0.3 0:00.07 python3 /usr/local/bin/simple_switch_CLI
835 root 20 0 107M 2816 2480 S 0.0 0.0 0:00.63 /usr/sbin/irqbalance --foreground
1069 kernoops 20 0 56948 420 0 S 0.0 0.0 0:00.15 /usr/sbin/kerneloops --test
27686 root 20 0 1047M 14400 4084 S 0.0 0.2 0:00.06 /usr/lib/snapd/snapd
1473 root 20 0 101M 4092 3008 S 0.0 0.1 0:01.84 sshd: root@pts/0
838 root 20 0 546M 9584 6468 S 0.0 0.2 0:00.36 /usr/sbin/NetworkManager --no-daemon
911 root 20 0 281M 4840 3840 S 0.0 0.1 0:00.23 /usr/lib/accounts-service/accounts-daemon
292 root 19 -1 86716 14488 13652 S 0.0 0.2 0:00.31 /lib/systemd/systemd-journald
633 systemd-r 20 0 70620 4252 3656 S 0.0 0.1 0:00.12 /lib/systemd/systemd-resolved
13408 root 20 0 22960 5536 3776 S 0.0 0.1 0:00.03 -bash
1195 root 20 0 1047M 14400 4084 S 0.0 0.2 0:00.31 /usr/lib/snapd/snapd
F1Help F2Setup F3Search F4Filter F5Tree F6SortBy F7Nice F8Nice F9Kill F10Quit
```

Conclusão:

O ambiente de instalação do compilador p4 precisa instalar um total de três componentes de software, respectivamente: protobuf, p4c, bmv2, sugerimos que leia as fontes originais para entender melhor o processo, problemas podem ocorrer, por isso este tutorial foi criado, devido à inúmeros problemas enfrentados durante um tutorial específico para: protobuf, p4c e bmv2.

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Fonte principal:

<https://www.programmersought.com/article/9444864088/>

Fontes auxiliares:

<https://www.sdnlab.com/19912.html>

<https://www.cnblogs.com/qg952693358/p/7463204.html>

<https://steeven.iteye.com/blog/2330830>

<https://www.cnblogs.com/qg952693358/p/5905536.html>

https://blog.csdn.net/zhangmeimei_pku/article/details/79479055

<https://www.sdnlab.com/22466.html>

<https://www.sdnlab.com/22512.html>

<https://www.cnblogs.com/ljy1227476113/p/10524035.html>

http://sunyongfeng.com/201705/networks/p4/repo_p4app.html

<https://p4.org/p4/getting-started-with-p4.html>