



UNIVERSIDAD DE BUENOS AIRES  
FACULTAD DE CIENCIAS EXACTAS Y NATURALES  
DEPARTAMENTO DE COMPUTACIÓN

# Haikunet: SDN programming language

Tesis presentada para optar al título de  
Licenciado en Ciencias de la Computación

Andrés Laurito

Director: Hernán Melgratti  
Codirector: Rodrigo Castro  
Buenos Aires, 2017



## HAIKUNET: A SDN PROGRAMMING LANGUAGE FOR DEBUGGING THE NETWORK

La princesa Leia, líder del movimiento rebelde que desea reinstaurar la República en la galaxia en los tiempos ominosos del Imperio, es capturada por las malévolas Fuerzas Imperiales, capitaneadas por el implacable Darth Vader. El intrépido Luke Skywalker, ayudado por Han Solo, capitán de la nave espacial “El Halcón Milenario”, y los androides, R2D2 y C3PO, serán los encargados de luchar contra el enemigo y rescatar a la princesa para volver a instaurar la justicia en el seno de la Galaxia (aprox. 200 palabras).

**Palabras claves:** Guerra, Rebelión, Wookie, Jedi, Fuerza, Imperio (no menos de 5).



## HAIKUNET: SDN PROGRAMMING LANGUAGE

In a galaxy far, far away, a psychopathic emperor and his most trusted servant – a former Jedi Knight known as Darth Vader – are ruling a universe with fear. They have built a horrifying weapon known as the Death Star, a giant battle station capable of annihilating a world in less than a second. When the Death Star’s master plans are captured by the fledgling Rebel Alliance, Vader starts a pursuit of the ship carrying them. A young dissident Senator, Leia Organa, is aboard the ship & puts the plans into a maintenance robot named R2-D2. Although she is captured, the Death Star plans cannot be found, as R2 & his companion, a tall robot named C-3PO, have escaped to the desert world of Tatooine below. Through a series of mishaps, the robots end up in the hands of a farm boy named Luke Skywalker, who lives with his Uncle Owen & Aunt Beru. Owen & Beru are viciously murdered by the Empire’s stormtroopers who are trying to recover the plans, and Luke & the robots meet with former Jedi Knight Obi-Wan Kenobi to try to return the plans to Leia Organa’s home, Alderaan. After contracting a pilot named Han Solo & his Wookiee companion Chewbacca, they escape an Imperial blockade. But when they reach Alderaan’s coordinates, they find it destroyed - by the Death Star. They soon find themselves caught in a tractor beam & pulled into the Death Star. Although they rescue Leia Organa from the Death Star after a series of narrow escapes, Kenobi becomes one with the Force after being killed by his former pupil - Darth Vader. They reach the Alliance’s base on Yavin’s fourth moon, but the Imperials are in hot pursuit with the Death Star, and plan to annihilate the Rebel base. The Rebels must quickly find a way to eliminate the Death Star before it destroys them as it did Alderaan (aprox. 200 palabras).

**Keywords:** War, Rebellion, Wookie, Jedi, The Force, Empire (no menos de 5).



## AGRADECIMIENTOS

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Fusce sapien ipsum, aliquet eget convallis at, adipiscing non odio. Donec porttitor tincidunt cursus. In tellus dui, varius sed scelerisque faucibus, sagittis non magna. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Mauris et luctus justo. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos himenaeos. Mauris sit amet purus massa, sed sodales justo. Mauris id mi sed orci porttitor dictum. Donec vitae mi non leo consectetur tempus vel et sapien. Curabitur enim quam, sollicitudin id iaculis id, congue euismod diam. Sed in eros nec urna lacinia porttitor ut vitae nulla. Ut mattis, erat et laoreet feugiat, lacus urna hendrerit nisi, at tincidunt dui justo at felis. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos himenaeos. Ut iaculis euismod magna et consequat. Mauris eu augue in ipsum elementum dictum. Sed accumsan, velit vel vehicula dignissim, nibh tellus consequat metus, vel fringilla neque dolor in dolor. Aliquam ac justo ut lectus iaculis pharetra vitae sed turpis. Aliquam pulvinar lorem vel ipsum auctor et hendrerit nisl molestie. Donec id felis nec ante placerat vehicula. Sed lacus risus, aliquet vel facilisis eu, placerat vitae augue.





*A mi viejo.*



## SUMMARY

1.. Introduction . . . . .	1
1.1. Motivations . . . . .	1
2.. Background . . . . .	3
3.. TopologyGenerator . . . . .	5
3.1. Key Concepts . . . . .	5
3.1.1. Examples of use . . . . .	5
3.2. Tutorial . . . . .	9
3.2.1. Installation . . . . .	9
3.2.1.1. Installation as a gem . . . . .	9
3.2.1.2. Installation as a binary . . . . .	9
3.2.2. Using the tool . . . . .	10
3.2.2.1. Use as a gem . . . . .	10
3.2.2.2. Use as a binary . . . . .	12
3.2.3. Implementing your provider . . . . .	13
3.2.4. Implementing your builder . . . . .	13
3.2.5. Network topology model . . . . .	13
3.2.5.1. Implementing your network topology model . . . . .	13
3.3. Limitations . . . . .	13
4.. Haikunet . . . . .	15
5.. Conclusions . . . . .	17



# 1. INTRODUCTION

## Motivations

*The best way to predict the future, is to invent it.*  
–Alan Kay



## 2. BACKGROUND





### 3. TOPOLOGYGENERATOR

#### Key Concepts

The topologygenerator is a tool for building a custom output file format out of a given network topology. The key concepts in this tool are the followings:

- **Provider**  
Will be in charge of everything which is concerned to the network topology, meaning that it will have to provide information about it's elements, how they are connected between each other, general properties of each of the elements, etc., as well as has the ability to change it's content, for example adding new elements to the network, creating new connections, deleting elements, etc.
- **NetworkTopology**  
Is an abstract representation of the network which will be build by several requests to the provider.
- **Builder**  
Builders will know how to create from a network topology the desired output. For each type of element in the network (for example host, link, device), we will have a builder.  
This element is easily implemented thanks to the network topology explained above, since this abstraction allow us to decouple from the real provider (it wouldn't be the same to build an element if the provider is Onos or OpenDayLight, since the way of getting the information from the element varies depending on the controller).
- **Output**  
Is what we are seeking, our main objective. This output can be either a file or multiple files, and will be generated by either one or multiple builders.

#### Examples of use

Understood the key concepts, let's understand how this elements relates one with each other with some examples of use. We will first start focusing in an abstract example, where we just have one provider and N type's of elements in the network as showed in the next image:

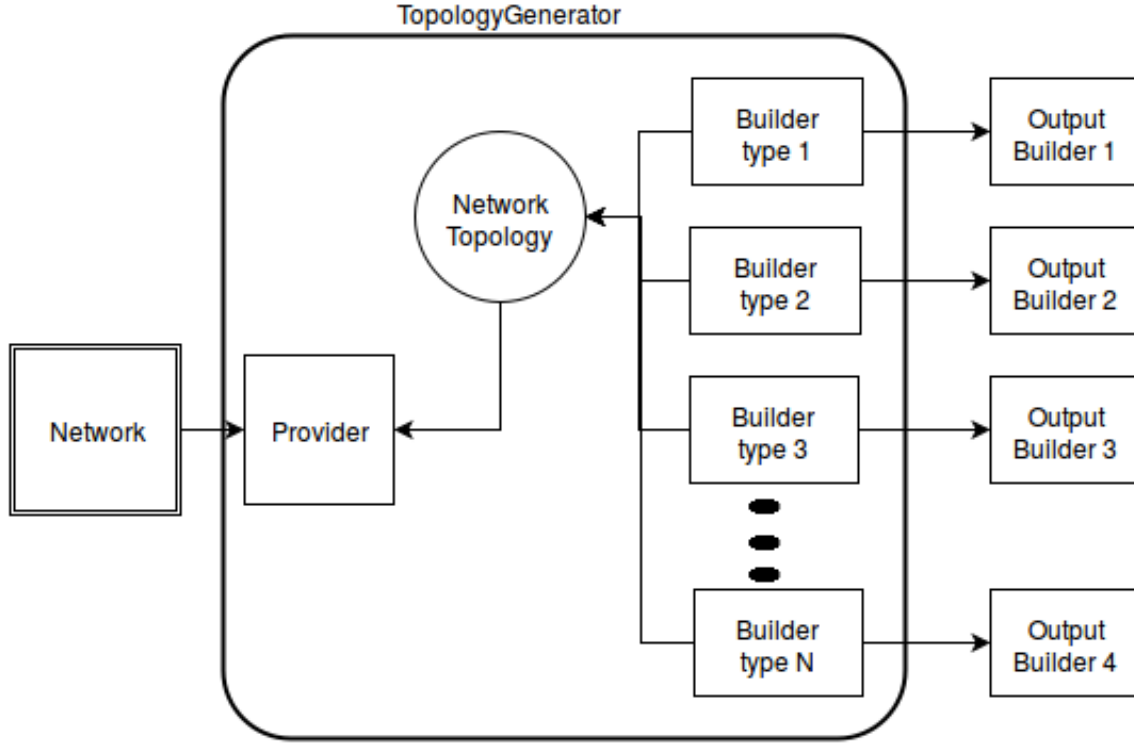


Fig. 3.1: Abstract interaction of elements with multiple outputs

In this image we can see how the elements explained above interact. The provider will communicate with the real network, in the image above the real network is represented as the network which is outside the topology generator, to get all the information necessary in order to create the network topology representation. This communication can either happen locally or remotely as we will see in one of the followings examples.

Once the representation is created, the builders are called to generate the output. In this example, we consider having  $N$  different types of elements in the network topology, which make us to have  $N$  different types of builders (1 per each type). Just to remark what was explained about the output, we are showing an example where we have one output per builder. This is not necessary the only case, as we can see in this other example:

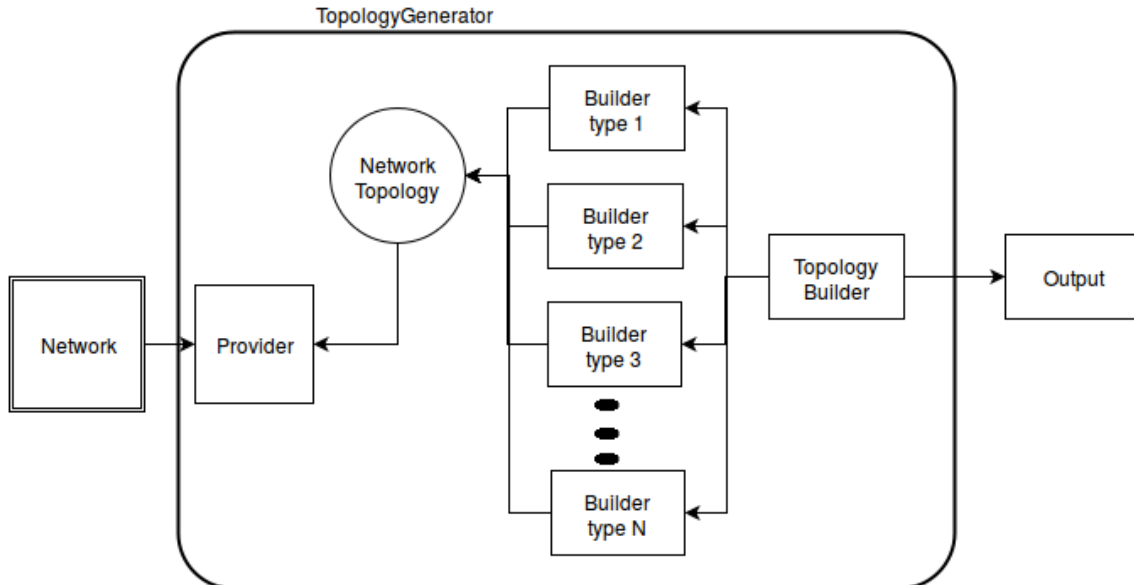


Fig. 3.2: Abstract interaction of elements with single output

As we can see in this case, the logic of joining all the outputs from each of the builder's type is made by a new builder called TopologyBuilder, which is the one who finally generate's the desired output.

Let's consider now a concrete example where we want to obtain a network from either ONOS or OpenDayLight controller, and then create a DEVS's model for running simulations. We will assume that we are interested in hosts, devices and links of the network, meaning that we will consider only three types of elements.

In this example, we will need to have two providers, one per each controller, three builders, one per each type, and one more builder which will have the logic of joining all the output's provided to generate one common output, the topology.pdm, as show next:

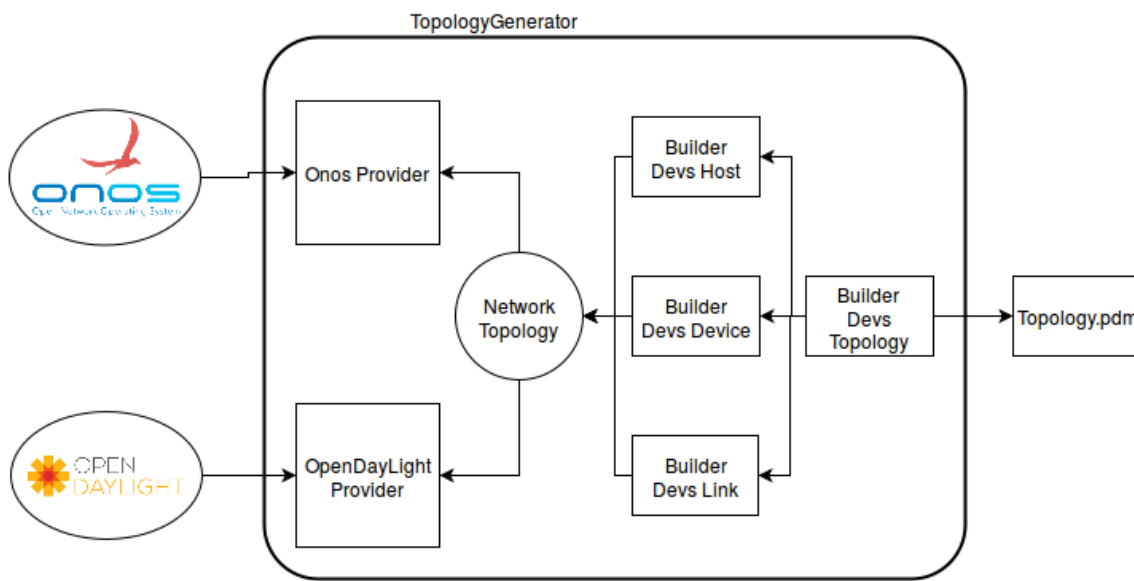


Fig. 3.3: Controller's example

Each of the providers in the image above, will have the knowledge to communicate with it's corresponding controller. In this example, the OnosProvider will encapsulate the logic to communicate with the Api Rest from the Onos controller, meanwhile the OpenDayLightProvider will do the same for the OpenDayLight controller.

The interaction with the controller can be either locally, for example this can happens if the controller is set up in the same machine where the topologygenerator is running, or remotely, for example if the controller is set up in a different machine and the communication is made via http. How to implement both possibilities will be further explained in the next section.

The output generated is a pdm which can be interpreted by the DEVS simulator.

What happen if we do not have a real network?, What if we have a representation of a network in a programming language, for example Ruby, and we want to create from this network a simulation to test properties?. Then we can use the topologygenerator as follow in the next image:

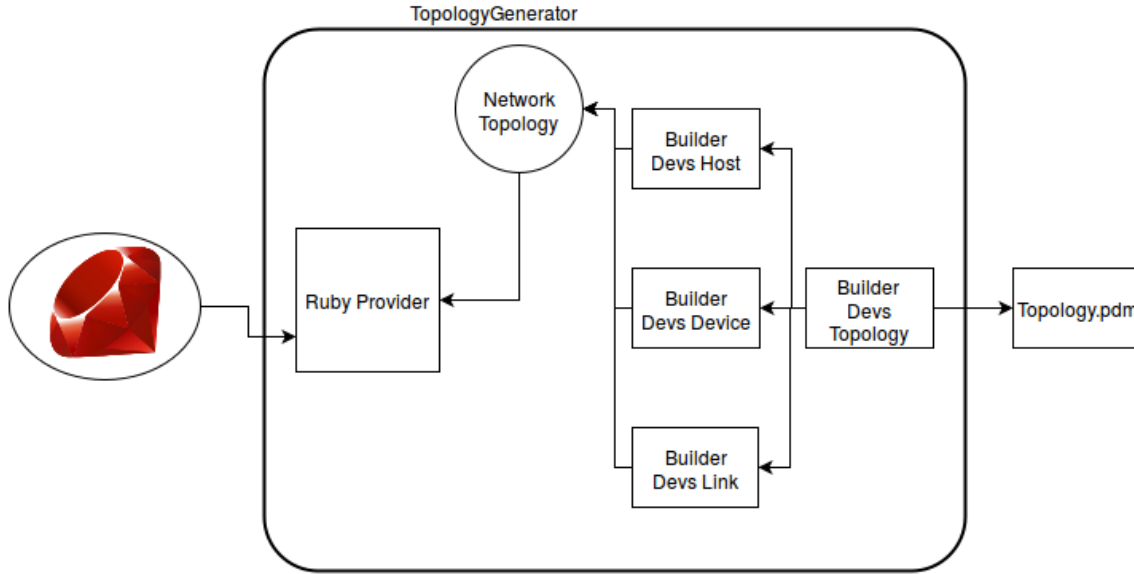


Fig. 3.4: Ruby as provider and DEVS as output

This image shows how it's just a question of creating a new provider, in this case the ruby provider, which will be in charge of having the knowledge of how to make the request to the script to obtain all the necessary information in order to create the network topology representation. Since we still want to create a simulation, the builders and the output is still the same.

In this previous example we show a powerful characteristic of the tool, which is that providers and builders are not related at all, meaning that changing a provider does not imply to change builders. This characteristic allow us then to create as much providers and builders as we want, and to connect them independently each other to generate as many desired output as we may want.

What would happen if we want to try out our custom topology written in Ruby, and test it in an Onos enviornment?, How could we manage to do this?. In this example we would like to have our ruby provider, as in the previous case, and builders that generates request to the ONOS Api as show in the following image:

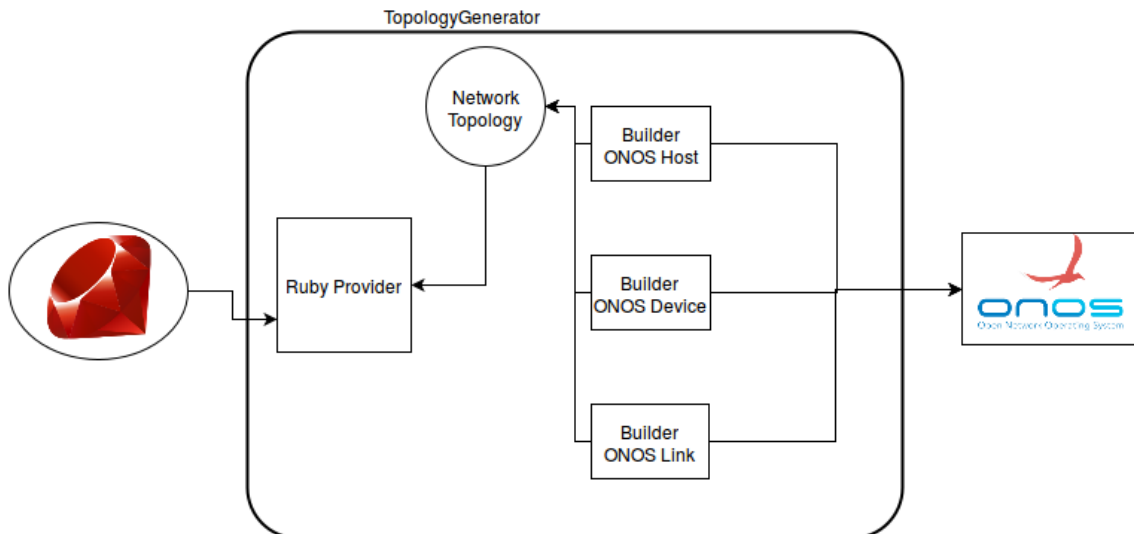


Fig. 3.5: Ruby as provider and ONOS as output

Each of the builder's in this case will generate requests to the ONOS Api that will create each of the elements in the SDN environment (this is a good example of the capability of SDN, since the environment allow us to create elements in the network). In this example, it's important to notice how malleable and easy results to change ONOS, which was though as a provider in previous examples, to a desired output.

With the examples showed, we have a good understanding in the power of the tool and how it is supposed to be used. In the following section we will provide a tutorial for using the topologygenerator, and we will implement some of the examples showed before.

## Tutorial

In this tutorial we will demonstrate how to install and use the topologygenerator tool. The tutorial was tested in a machine running Ubuntu 16.04, however should work in any machine which has a ruby version of 2.0 or major installed.

## Installation

You will need to have Ruby installed in your machine. We recommend for this installing the ruby version manager (RVM), however any installation should be fine.

Once ruby is installed, you can proceed now to install the topologygenerator. For doing this, you will have two options:

- Installing it as a gem  
You should go for this option in case you are thinking in using the topologygenerator as a library of your Ruby project.
- Installing it as a binary  
Select this option in case you are not interested in adding the topologygenerator as a library of any project. In this case, you will use the topologygenerator as a binary.

Per each option please refer to the corresponding subsection listed below.

### Installation as a gem

Add this line to your application's Gemfile:

```
gem 'topologygenerator'
```

And then execute:

```
$ bundle
```

Or install it yourself as:

```
$ gem install topologygenerator
```

### Installation as a binary

**Pre-requisite:** Have installed and configured a git client.

Execute the followings lines (replace **TOPOLOGY\_DIRECTORY** with the corresponding path):

```
$ git clone git@github.com:andyLaurito92/topologygenerator.git
$ sudo ln -s "$TOPOLOGY_DIRECTORY/lib/createTopology.rb" /usr/bin/
  topologygenerator
```

## Using the tool

How to use the topologygenerator will depend in which of the installation's guide you have done, however both ways are not so different and remember that you can always have the tool installed as a gem and a binary at the same time. In case you have installed the tool as a binary, we encourage you to first read the Use as a gem section, and then proceed to the Use as a binary section, since it still will be useful.

Both tutorials require you to have installed either Onos or OpenDayLight Controller and mininet.

First we will guide you in how to use the tool using the builders and providers implemented as examples, and then you will get hands on into the code and implement a provider and a builder. In both using examples, we will use the ONOS and OpenDayLight providers, and the PDM and Ruby builders.

NO ESTOY SEGURO SI SE PUEDEN USAR LOS BUILDERS Y PROVIDERS POR DEFECTO EN LA INSTALACIÓN DE LA GEMA, PORQUE NO SE SI RUBY TE DEJA ACCEDER A TODO EL PROYECTO DE LA GEMA, O SOLO AL BINARIO. TENGO QUE PROBAR ESTO, PERO EN CASO DE QUE NO SE PUEDA, ENTONCES EN LA INSTALACIÓN DE LA GEMA NO TENGO LOS BUILDERS Y PROVIDERS DE EJEMPLO, POR LO QUE TENGO QUE PENSAR EN COMO HACERLO ACCESIBLE PARA ESTOS MUCHACHOS.

### Use as a gem

We will use the topologygenerator as a gem, meaning that will be part of your ruby code.

Using the tool is really straightforward, first we require the gem in the script as follows:

```
require 'topologygenerator'
```

And now we can create a new topologygenerator instance as follows:

```
my_topology_generator = TopologyGenerator.new({
  "source" => "ONOS", #Actually ONOS, OPENDAYLIGHT, OBJECT and
                     #CUSTOM are the options supported
  "directory_concrete_builders" => "builders_examples/
                                   pdm_builders", #The directory where builders are located
  "output_directory" => "output_directory", #The directory where
                     #the output will be saved
  "uri_resource" => "http://127.0.0.1/onos/v1/" #Must be the
                     #rest api uri if either ONOS or OpenDayLight is choosed or
                     #the path of a file if CUSTOM is choosed. In case OBJECT is
                     #choosed, you will have to provide a valid instance of
                     #Topology.
})
```

Let's go through the code in more detailed. What we are doing in this example is to tell the topologygenerator that we are going to use the ONOS provider, this is done just by passing as argument "ONOS" to the **source** key, and the DEVS builders, for doing this you just need to detailed the path where the builders are located to the **directory\_concrete\_builders** key. Since we have the topologygenerator gem installed, the environment has already loaded the path to the project, so there is no need to use the full path.

The next thing that you have to do is set the path where the output is going to be stored, for doing you just need to define the **output\_directory** key.

Finally since we are using the ONOS provider, we need to provide the uri from the ONOS's

api. As you can see, this is done just by defining the **uri\_resource** key in the constructor.

After creating our topologygenerator instance, we can now proceed to generate the desired output by writing the following line in the code:

```
my_topology_generator.generate
```

The reader can have already noticed that what we are doing in this example, is implement the Controller's use case detailed in the previous section.

Before getting into the next example, let's go in more detailed in two of the four providers detailed above, the **CUSTOM** and **OBJECT** providers.

For using the **CUSTOM** provider, you will need to provide the path to the ruby network topology model file, which it would contain a valid model. Assuming that your model is in the following path: *models/my\_network\_model/my\_network.rb*, this is how you have to create the topologygenerator's instance:

```
my_topology_generator = TopologyGenerator.new({
  "source" => "CUSTOM",
  "directory_concrete_builders" => "builders_examples/
    pdm_builders",
  "output_directory" => "output_directory",
  "uri_resource" => "models/my_network_model/my_network.rb"
})
```

For further information of what is this model and how you can program one, please go ahead to the *Network topology model* section.

For using the **OBJECT** provider, you will need to provide a valid instance of topology. Let's suppose that you have a variable called *my\_topology* with a valid instance class, this is how you have to create your topologygenerator's instance:

```
my_topology_generator = TopologyGenerator.new({
  "source" => "OBJECT",
  "directory_concrete_builders" => "builders_examples/
    pdm_builders",
  "output_directory" => "output_directory",
  "uri_resource" => my_topology
})
```

We encourage you to read more about the Topology class in the the topologygenerator API. In there you will be able to find examples in how to build a valid instance of this class.

Now that we have understood the providers, let's go through another example. Suppose that you want to use the tree topology network model located at *network\_topologies\_examples*, for creating a simulation in PowerDevs. This is the way of doing this:

```
my_topology_generator = Topologygenerator.new({
  "source" => "CUSTOM",
  "directory_concrete_builders" => "builders_examples/
    pdm_builders",
  "output_directory" => "output",
  "uri_resource" => "network_topologies_examples/tree_topology.
    rb"
})
my_custom_topology = topology_generator.generate
```

What about if you want to use an OpenDayLight controller running in your local host, and from this network get a ruby representation model?. Then you will have to do as follow:

```
my_topology_generator = Topologygenerator.new({
  "source" => "OPENDAYLIGHT",
  "directory_concrete_builders" => "builders_examples/
    ruby_builders",
  "output_directory" => "output",
  "uri_resource" => "http://localhost:8080/restconf/operational/
    network-topology:network-topology/topology/flow:1/"
})
my_custom_topology = topology_generator.generate
```

As you may have already noticed, using the topologygenerator tool is really straightforward and flexible. We encourage you to keep on trying the tool with another builders and providers!. When you think that you are ready, you can jump on to code your first provider in the **Implementing your provider** section!.

#### Use as a binary

These are the commands that you need to know for using the topologygenerator as a binary:

- **-n (source name)** : The name of the provider. This can be matched with the source key in the topologygenerator's constructor in the previous section, but you have three providers instead of four (OBJECT is not supported in this way of use).
- **-o (output directory)** : The path where the output will be stored. This can be matched with the output\_directory key in the topologygenerator's constructor in the previous section.
- **-u (uri resource)** : A path to a ruby network model in case **CUSTOM** provider was selected, or an uri to an API if either **ONOS** or **OPENDAYLIGHT** were selected. This can be matched with the uri\_resource key in the topologygenerator's constructor in the previous section.
- **-d (directory concrete builders)** : A path to a directory where the builders are located. This can be matched with the directory\_concrete\_builders in the topologygenerator's constructor in the previous section.

Remember that the path specified by argument can be relative, and in this case will be looked from the place where you are executing the command.

Suppose now that you want to use the topologygenerator for reading a network from ONOS, and build a simulation model. This is how you can do this:

```
$ topologygenerator source -n ONOS -o output_directory -u http
  ://127.0.0.1/onos/v1/ -d builders_examples/pdm_builders
```

In case you want to try out the tree topology model for building a simulation, you can do it as follow:

```
$ topologygenerator source -n CUSTOM -o output_directory -u
  network_topologies_examples/tree_topology.rb -d builders_examples
  /pdm_builders
```

Or if you want to build a ruby model from an OpenDayLight network you can do the following:



```
$ topologygenerator source -n OPENDAYLIGHT -o output_directory -u  
http://localhost:8080/restconf/operational/network-topology:  
network-topology/topology/flow:1/ -d builders_examples/  
ruby_builders
```

Now that you know how to use the tool, let's proceed to get hands on and program your first provider!.

## Implementing your provider

## Implementing your builder

## Network topology model

Implementing your network topology model

## Limitations



## 4. HAIKUNET



## 5. CONCLUSIONS

