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MASTER THESIS

TITLE: Management of a LTE Radio Access Network Through Orchestration Platforms

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Resumen

Este proyecto propone una opción de software libre para la implementación y optimización de una red de acceso al radio enfocándose en la tecnología con fines pedagógicos para que los estudiantes puedan entender 5G, el software RAN Simulator es el elegido para este propósito, debido a la capacidad de comunicarse con el software ONAP que es el software que en un futuro cercano será el encargado de operar tanto como funciones virtuales de red así como funciones físicas de red.

Este trabajo ha sido utilizado para optimizar una propuesta de adición de una nueva señal portadora en LTE que podrá ser descrita como el inicio de implementación de una red 5G, Esto sumado con las herramientas ofrecidas por RAN Simulator, es posible analizar y corregir problemas que se puedan presentar en una red de acceso al radio relacionados con la asignación de identificadores físicos de las celdas.

La consecuencia de mejorar una red con este tipo de herramientas puede verse reflejada en los medidores de desempeño, donde caídas de llamada, errores durante las transferencias de datos entre celdas, y fallas en las transmisiones de datos hacia los usuarios pueden ser mejoradas o evitadas, esto impactando directamente en mejores servicios ofrecidos a los usuarios y mejoramiento de la red.

Entender, operar y llegar a conclusiones sobre el software RAN Simulator, es de ayuda para la implementación en redes ya operando, además de la posibilidad de comunicación con ONAP. La conjunción de RAN Simulator con ONAP será una gran herramienta para el mejoramiento e implementación de cambios en una red.

Abstract

This project propose a functional free software option for the implementation and optimization of a Radio Access Network (RAN) focused on a pedagogical purpose to the students can understand the 5G technology. The software called RAN Simulator it is the one selected with this propose due to the capability and option to communicate with ONAP Software which is in the future the software selected to operate Virtual Network Functions (VNF) and Physical Network Functions (PNF).

This project has used to optimize a proposal of new carrier add on Long Term Evolution (LTE) which can be described as a new 5G network, this with the tools provided by RAN Simulator which it is capable to analyze and help to avoid and correct issues in a real RAN related to Physical Cell Identification (PCI).

The effect of improve a network with this kind of tool can be seeing in the Key Performance Indicators (KPI), where drop calls, errors during hand over, and missing information sent to and from the user equipment can be improved and avoided, this with the immediate effect of offer better service to the users and improve the network.

Understand, operate and get conclusions of the RAN Simulator software will be helpful to implement in operating networks and with the option of communication with ONAP, the ONAP software will be a complete option for operators due to the possibility of improvement and implement changes to the network.

CONTENTS

1. Introduction.

The mobile technologies has evolved since the beginning where the only capability was process voice through the network, the implementation of new services, the mass adoption and the increasing data traffic demand has pushed to the network developers to evolve the technology in usage, where each improvement and new technology implemented is called generation.

The current technology in deploying it is 5G, which has in particular the characteristic of this technology will not just be a “business-as-usual” evolution of 4G networks with new spectrum bands, higher spectral efficiencies and higher peak throughput, but also offer new services and business models, the main 5G service types, typically considered are extreme mobile broadband with data rates up to several Gigabits per second, in some areas and reliable broadband access over large coverage areas, massive machine-type communications requiring wireless connectivity, millions of power-constrained sensors and actuators, all these factors has represented a huge challenge due to the limited spectrum availability and the limited number of devices that can be connected to the network.

Due to the diverse and extreme requirements of the mentioned main 5G service types, it is clear that the 5G Radio Access Network (RAN) must be designed to operate in a wide range of spectrum bands with diverse characteristics, such as channel bandwidths and propagation conditions. it must further be able to scale to extremes in terms of throughput, number of devices, connections, etc.

The present document offer an analysis of a software focus on the optimizacion and development of RANs, explaining the procedures for the improvement and mitigation of issues presented in a real case scenario, simulating the implementation of a carrier aggregation focused to provide 5G services in a high demanded area, this in form of a practical manual for students and professionals, to whom are interested on know a new proposal of software to improve RANs and the ways of working of this kind of tool.

1.1. Objectives.

The overall objective of the project is an evaluation of an option offered to optimize RAN, for the function of differentiating the Physical Cell Identification (PCI), which is one of the most common issues at the moment of the deploy of a network, causing issues to the calls supported by the RAN and impacting in the Key Performance Indicators (KPI) of the network.

For this case, the software to analyze will be RAN Simulator which is the tool created for the RAN to interact with ONAP, seeking for the ways of working of the tool, how it manages the information and what are the main functions, this with the purpose of have clear a option offered by this tool and if can be implemented for the optimization of real and functional networks.

To have an evaluation of the tool, with the objective to see if at the end of the document, the tool can be used to the purpose of helping to fix issues on that RAN, regarding PCI confusion and collision, it will be considering the next factors:

- Interconnection to ONAP
- Capability to load and analyze network configurations from a external source.
- Option to modify on the system values as PCI and Neighbors relations in order to solve potential issues on PCIs.
- Figure out if the tool is easy to use and understandable in order to consider it as a good option to perform network modifications.

To analyze the entire ecosystem offered by RAN Simulator and ONAP, the connectivity and interaction between these two tools will be tested to confirm the functionalities offered, the chance to get a functional network configuration from ONAP and been transferred to RAN Simulator for optimization.

At the end of this memory the steps and process followed for the installation and usage of the tool, can be used as a practical manual for students and professionals in order to help them to know how to load, manage and improve issues presented by a RAN as well in real or Simulated Scenarios.

1.2. Context.

Nowadays the use of mobile technology, has grown enormously and the need to cover all the demands of the users, has pushed to the telecom operators and the telecom industry to deploy a new type of mobile communications network, which has been called generation, each of them has their own characteristics and features, where for each release has come with improvements and new features, starting from the 1st Generation in 1980 where the capability of the network was only for voice calls, the usage of the network the needs to offer better and more services, has pushed to the industry to develop new technologies and improve the previous ones.

Currently, the new growing technology it is called 5G according with the numeration followed, which can be described as a direct evolution of the already implemented technology Long Term Evolution (LTE), which the usage of the subscribers and the new technologies coming, has force to the industry to implement improvements to the current deployment network.

The industry is paying special attention to the immediate future, where the data rate demanded by users in downlink and uplink has increase significantly, the new applications and services are demanding streaming of real time video in High definition, streaming of audio in high quality and at the same time browsing web pages with a big number of media in high quality, this is representing a real challenge to the current networks, these factors plus the growing number devices connected to the mobile networks, is making hard for the current technology provide high speed throughput and radio access to all the devices with the intent of get connectivity.

In this context the new growing technology called 5G, has the big challenge to cover all the need of the future which is offer high speed throughputs and ensure connectivity to a several number of devices.

1.3. LTE Radio Access Network (RAN).

In contrast to the circuit-switched model of previous mobile technologies, Long Term Evolution (LTE) has been designed to support only packet switched services. [14]

The access network of LTE, simply consists of a network of nodes, for normal traffic, there is no centralized controller node, hence the LTE RAN architecture is said to be flat. [2]

The RAN nodes are normally interconnected with each other by means of interface known as “X2”, this interface is the one incharge of perform handovers between cells where a neighbor relation is defined. [15]

On the network side, all of these functions reside in the RAN nodes named as eNodeBs, each of them can be responsible for the management of multiple cells, unlike previous technologies, LTE integrate the radio controller inside the eNodeB [2], this avoid the need of a central node for this purpose.

1.4. Physical Cell Identification (PCI).

Nowadays an ordinary LTE network can reach up to 100 Mbit/s [14]. in order to reach this kind of speed, LTE networks should be well optimized. As an initial step; optimization and design part of the LTE defines the name of the cells so, that users can camp on the best server cell and handover the other cells while the user is moving [14]. One of the basic functions in any network is the cell search. During this procedure, time and frequency synchronization are established between the user equipment and the network. To identify the cells, the PCI is acquired. This is achieved by the cell search procedure [14]. The PCI is an essential configuration parameter of a radio cell. It identifies the cell in mobility functions such as cell reselection and handover. The PCI is also used to determine the location of the resource elements.

If cells PCI cannot be assigned well, mobile users cannot read the actual signals, cannot camp on the LTE networks or data throughput is degraded even worse, it is dropped [14]. This have direct impact to the user experience and degradation of KPIs.

PCI consists of two signals; Primary Synchronization Signal (PSS) and the Secondary Synchronization Signal (SSS) [14]. The detection of these two signals not only enables time and frequency synchronization, but also provides the UE with the physical layer identity of the cell, this informs to the UE [14].

PCI is calculated by using PSS and SSS in a formula:

$$PCI = PSS + 3(SSS)$$

SSS is the PCI group with values from 0 to 167 and PSS is the identity within the group with values from 0 to 2. This arrangement creates 504 unique PCIs which can be assigned to the network [14].

1.5. PCI collision and PCI confusion.

The PCI conflict problem that can occur in LTE radio networks, confusions and collisions, the steps taken towards achieving the best approach to detect PCI conflicts, by using different models to analyze KPI [3].

Each LTE cell has two identifiers, with different purposes, the global cell id and the PCI. The global cell Id is used to identify the cell from an operator, administration and management perspective [3]. The PCI has a value in the range of 0 to 503, and is used to scramble the data in order to allow mobile phones to separate information from different eNodeB [3]. Since LTE network contain a much larger of cells than the 504 available numbers of PCIs, the same PCI must be reused by different cells, however, an UE, which is any device used directly by and end-user to communicate, cannot distinguish between two cells if both have the same PCI and frequency bands; this phenomenon is called PCI conflict [3].

PCI conflicts can be divided into two situations, PCI confusion and PCI collisions.

PCI confusion occurs whenever a eNodeB cell has two different neighbor eNodeB cells with equal PCI and frequency [3].

A good PCI plan can be applied to avoid most PCI conflicts. By contrast, it can be difficult to do such a plan without getting any PCI conflicts in a dense network, however, network changes, namely increase power of a cell and radio channel fading, can lead to PCI conflicts, these changes might result in a mobile phone that detects a cell different from one of the PCI plan. PCI conflicts can lead to an increase of dropped calls due to failed handovers as well as an increased channel interference [3].

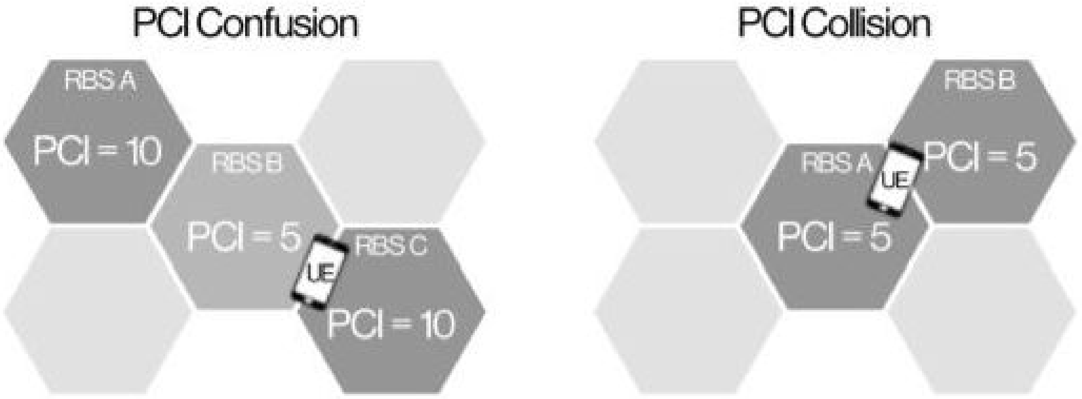


Figure 1.1 PCI Collision and PCI Confusion.

1.6. Coordination between cells and bands.

Going forward it is anticipated that RANs will become more heterogeneous, composed of multiple layers with different cell sizes and bandwidths, which calls for a tighter interworking between technologies and cell layers to ensure a seamless use experience and maximum spectral efficiency [2].

Radio coordination between cells and bands is becoming increasingly important to maximize spectrum efficiency and user experience. Generally speaking, radio coordination mechanism can be categorized as: [2]

- Mobility management (handover).
- Traffic management (load balancing).
- Carrier aggregation.

1.7. Coming technology: ONAP.

Created in 2017, the ONAP project brings together over 50 of the largest network operators, cloud operators and technology providers from around the world, with ONAP, network operators will be able to handle both Physical Network Functions (PNF) and Virtual Network Functions (VNF) [16].

This helps to the operators to keep their equipment already acquired reducing cost of investment in a future and prepare the network for the immediate future with VNFs [16].

As a cloud native application that consists of numerous services, ONAP requires sophisticated initial deployment as well as post-deployment management [16].

The operators will need to, in real-time, optimize the performance of the 5G services. This optimization will require dynamic configuration of relevant 5G radio and backhaul network parameters. To date, optimization functions have been realized in 3G and 4G networks via vendor hardware and software. ONAP will be capable to design and implement an open system for 5G optimization [16].

1.8. ONAP and the telecom industry's open-source journey.

Network operator's ability to capitalize on the opportunities arising from new technologies such as the cloud and 5G requires a significant reduction in the fragmentation and complexity within the operations support area. The open networking platform ONAP is an open source initiative assigned to overcome this challenge by clarifying industry expectations. Its provides a modular architecture and a common environment for a number of operational processes, as well as end to end service life cycle management across multiple networks and technologies [13].

In the past decade the telecom industry has seen rapidly growing demand, more users, devices and applications, coupled with rising expectations in terms of speed and service performance, this has lead to a massive technology revolution with several new technologies across the stack, as a result networks have become massive and increasingly complex to manage. The current operations support systems paradigm is not capable of efficiently managing the continuously acceleration number of network nodes, technologies, software entities, devices, users, and so on, without a dramatic increase in operation expenses, the only way to avoid management cost that rise in proportion to the growth in the numbers of entities, is to leverage automation. Adaptive policy decision based on artificial intelligence, and machine learning can further optimize the automation [13].

2. Analysis.

The description of the software RAN Simulator, the tool selected to the execute of the exercise due to the capability of immediate interconnection with ONAP, the option of import network data from an external source, against other options of software created with the purpose of the optimizacion and solution of PCI issues as Mentum Planet where this software is based on business and sell licenses, the lack of immediate interconnectivity to ONAP. RAN Simulator offer a good advantage against its competitors, for been free software, made with the objective of been a complement of ONAP and the possibility to use it for pedagogical purpose without the need of get a expensive license.

The situation raised for the demonstration of the capabilities of a tool focus on correction PCIs issues, has been planted as a real case scenario, where a simulation of a new carrier will be added to offer 5G services to the users, for any carrier aggregation project is needed to perform a PCI plan, in order to determinate and define the PCI for each cell to avoid issues as PCI collision and confusion, in the next chapter the idea to test the planted situation in one iconic place as a public plaza, taking into account the distribution of the cells and defining the PCI distribution.

To confirm the proper functioning of the tool, an initial configuration has been loaded, this network configuration can be taken as a simulation, due to the cells are the default from the tool.

To test the concept and functionalities, in the below chapter, will be show how are the basic capabilities of the RAN Simulator tool, and what are the results when of an initial approach.

2.1. RAN Simulator.

The RAN Simulator (RAN-SIM) it is a software developed to work together with the ONAP system, this in order to simulate a RAN to be designed and optimized, also can be loaded from a live network managed by ONAP, or an independent design loaded from a configuration file in the files of the system,

The main purpose of this tool is help in the design and optimization of the PCI, were the tool will help to identify where can be collisions or confusion with the design and assignation of PCIs, if there exist any of this problems, the issues can affect the services provided by the RAN as problems in handovers, not attaching to the right cell or sector, deny of service due to the UE is looking for a specific PCI [10].

One of the most important advantages the use of this software it is designed to work along ONAP software, using a netconf server which will communicate to the RAN Simulator to ONAP, sharing information about the network architecture and details about the nodes [12].

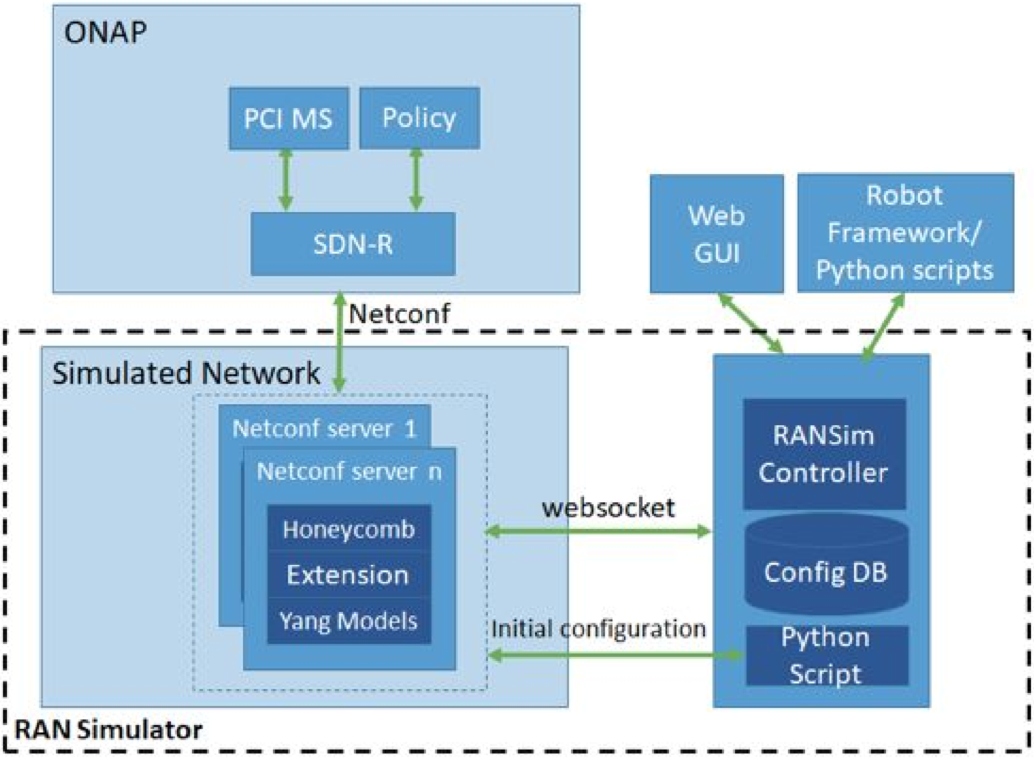


Figure 1.2 RAN Simulator Architecture

The tool once it is installed and the file configuration has been uploaded, the software will analyze the cases of the cells loaded and remark the status of each cell according with the below cases: [12]

- Cell has no collision confusion.
- Cell has a collision.
- Cell causes a confusion.

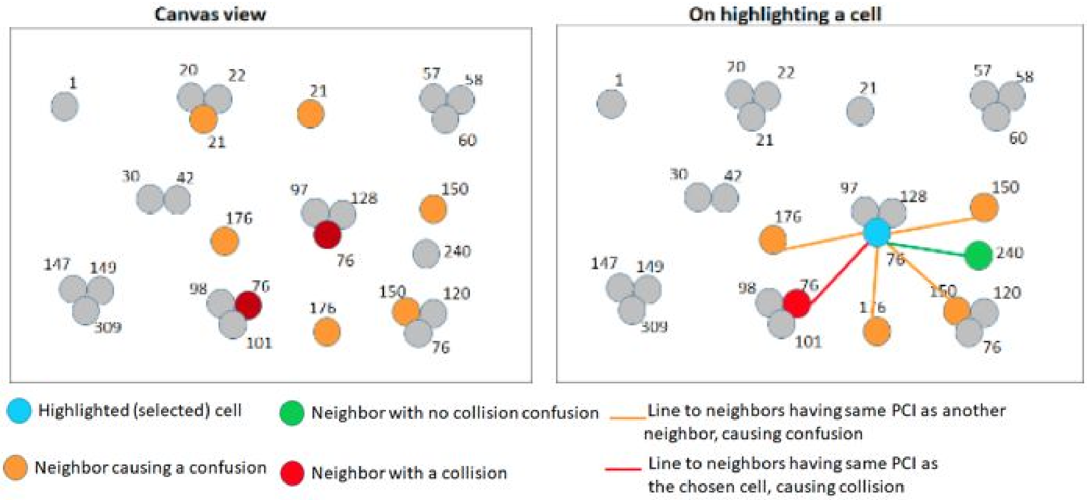

Canvas view
On highlighting a cell
Highlighted (selected) cell
Neighbor with no collision confusion
Line to neighbors having same PCI as another neighbor, causing confusion
Neighbor causing a confusion
Neighbor with a collision
Line to neighbors having same PCI as the chosen cell, causing collision

Figure 1.3 Demo of RAN Simulator Cell Selection

2.2. Applied Concept.

RAN Simulator has the function of remark the situation of each cell, regarding the PCIs added as neighbors on the network topology, this can be done filling the details of each cell, with the configuration file or by the GUI, the values requested for this propose are the below:

“networkId” This is the identification of the network who belong this cell, this is defined by the network operator.

"nodeId" The value which will be the identifier on the network and the name used by the tool to identify neighbors.

"physicalCellId" The identification PCI which will be analyzed by the tool.

"pnfName" This value is the name of the PNF, a common name defined by the operator to identify the site with a regular name.

“sectorNumber” this is an identification to define the number of cell which will be defined from 0 to 2.

“latitude” Is a geographic coordinate that specifies the north–south position of a point on the earth's surface. This cases the position of the cell in a geographic coordinate.

"longitude" Is a geographic coordinate that specifies the east–west position of a point on the earth's surface. This cases the position of the cell in a geographic coordinate.

"neighbor" This definition will be outside the cell definition on the script, it is a list of node identifications that will be a neighbor relation and will be consider it for the analysis.

The definition of a cell must be as below, this in order to be read by the RAN Simulator and can be analyzed.

```
{
 "cellList": [
  {
   "Cell": {
    "networkId": "ran-1",
    "nodeId": "CCL00118_R01_5H_1_N",
    "physicalCellId": 126,
    "pnfName": "CCL00118",
    "sectorNumber": 0,
    "latitude": "37.79013062",
    "longitude": "-122.4101105"
   },
   "neighbor": [
    {
      "nodeId": "CCL00118_R01_5H_2_N",
      "blacklisted": "false"
    },
    {
      "nodeId": "CCL00118_R01_5H_3_N",
      "blacklisted": "false"
    },
    {
      "nodeId": "CCL00418_R01_5H_1_N",
      "blacklisted": "false"
    },
    {
      "nodeId": "CCL00418_R01_5H_2_N",
      "blacklisted": "false"
    },
    {
      "nodeId": "CCL00418_R01_5H_3_N",
      "blacklisted": "false"
    {
      "nodeId": "CCL09103_R01_5H_3_N",
      "blacklisted": "false"
    }
   ]
  },
```

For this exercise has been uploaded a small example for a no optimized network, where can be seeing the three cases of the system can identify on a network: cell has no collision or confusion, cell has a collision, cell causes a confusion, cell has a collision and causes a confusion.

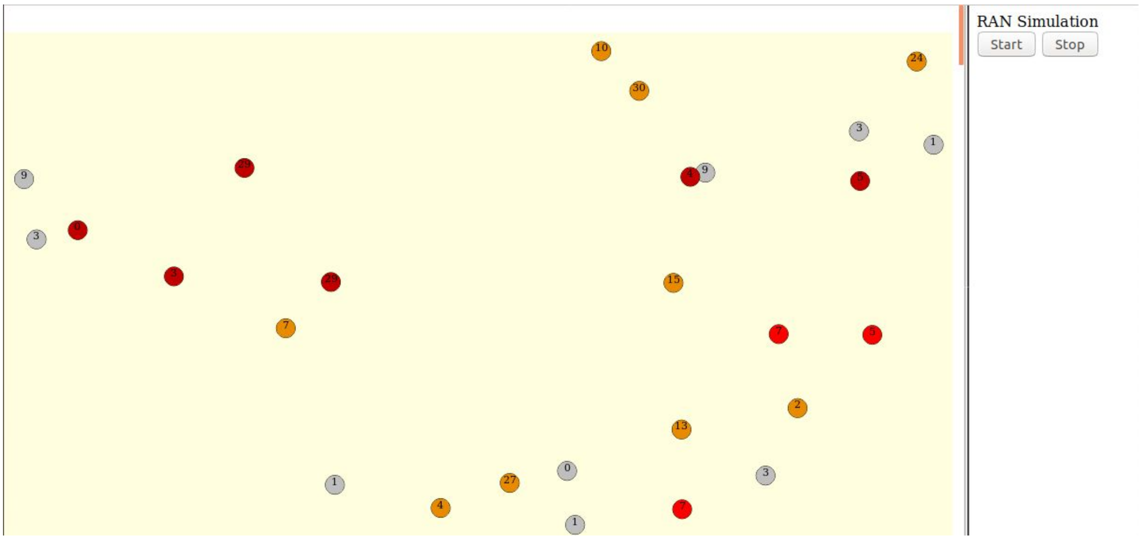


Figure 2.1 Primal state of Default Network

How can be observed on the image above, the representation of the network loaded on the RAN Simulator need to be optimized, due to it can be observed some cells are showing issues or collision and confusion, in order to clear the issues presented and analyzed by the system.

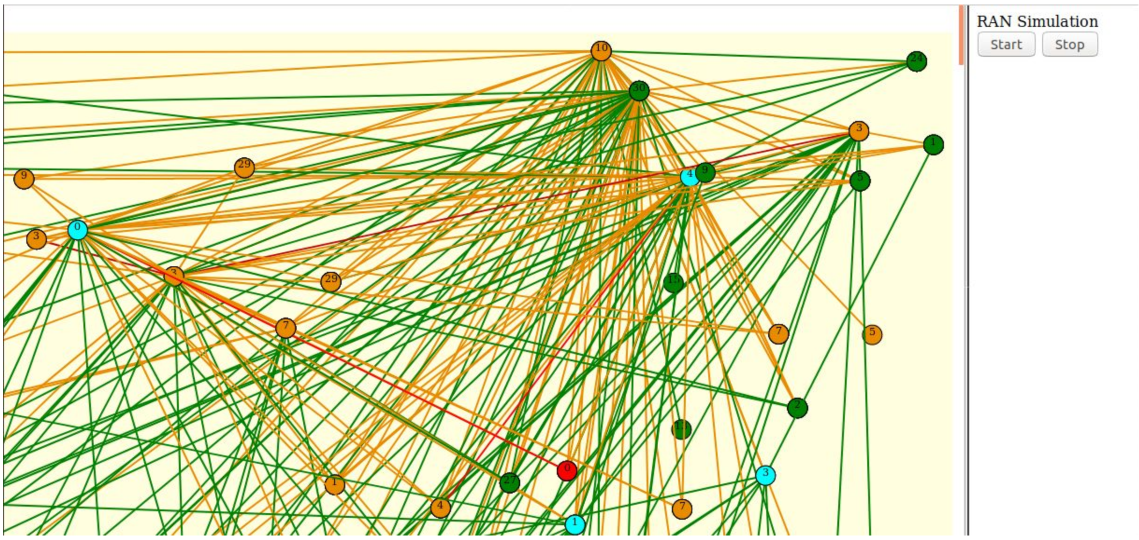


Figure 2.2 Neighbors Relations with Confusion of Default Network

The image above shows the representation of X2 interfaces between sites, where the neighbors relations are defined, it can be observe in yellow line pointing several cells defined as neighbor with the issue of confusion, and the green shows the cell without any issue presented in this case.

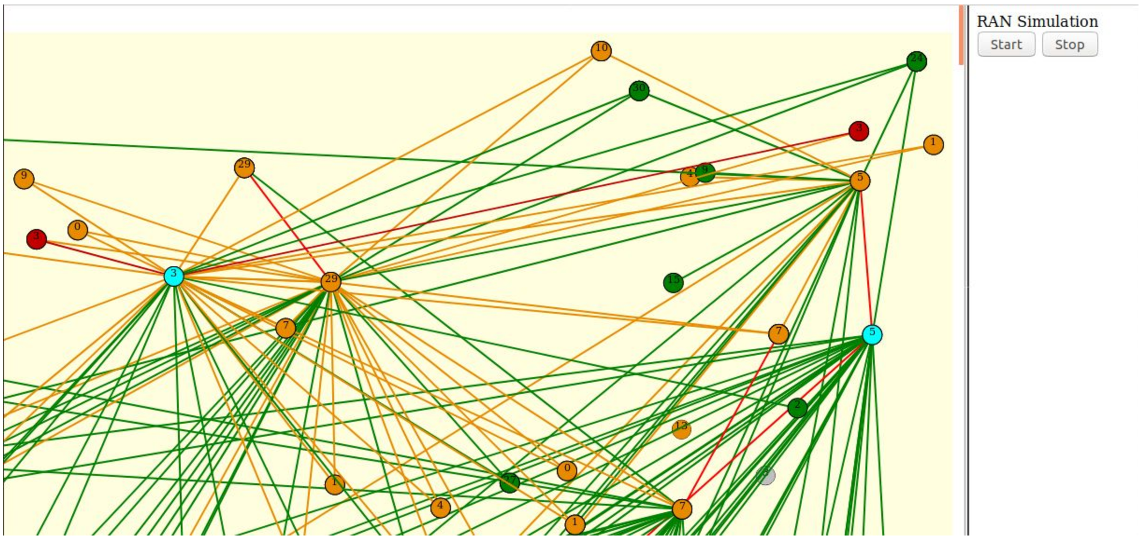


Figure 2.3 Relations with Collision issue of Default Network

The image above shows the representation of X2 interfaces as neighbors relations of the cells with the issue of collision, where the red lines pointing to the cell which has the issue of collisions, the yellow points the ones with the issue of confusion, and the green lines point the cells without any issue with the consulted cell.

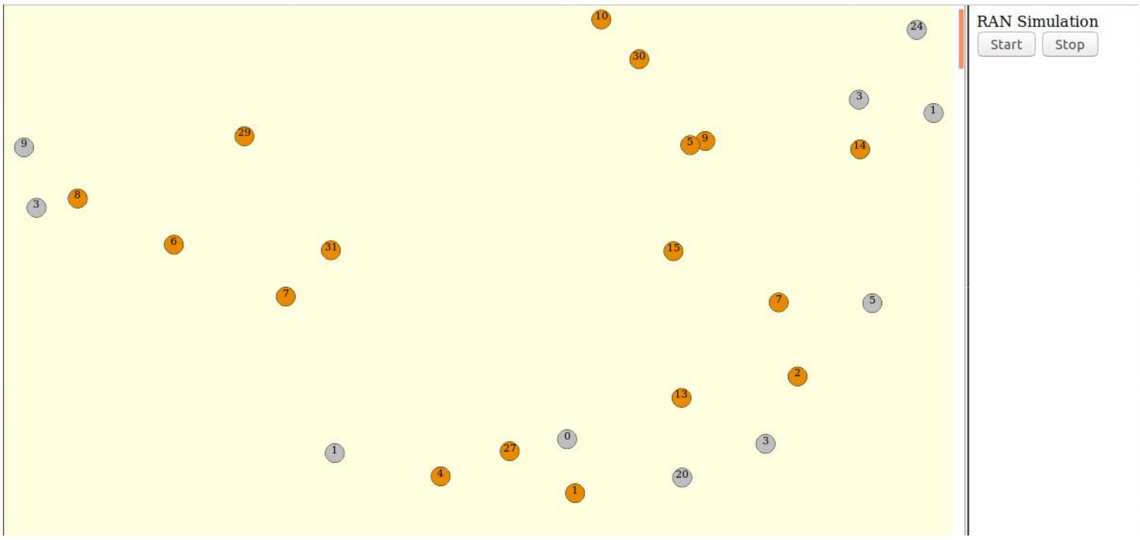


Figure 2.4 Optimization of cells with collision issue of the Default Network

The image above shows the results after the optimization of the cells with collision issues, the process to clear this issues were redefining the PCIs for new values not used for the close sites and defined as direct neighbors of the cell with the issue, and delete neighbor relations with low probability of use, far from the cell with the issue, this results in a network clear of collision issues as can be seen above.

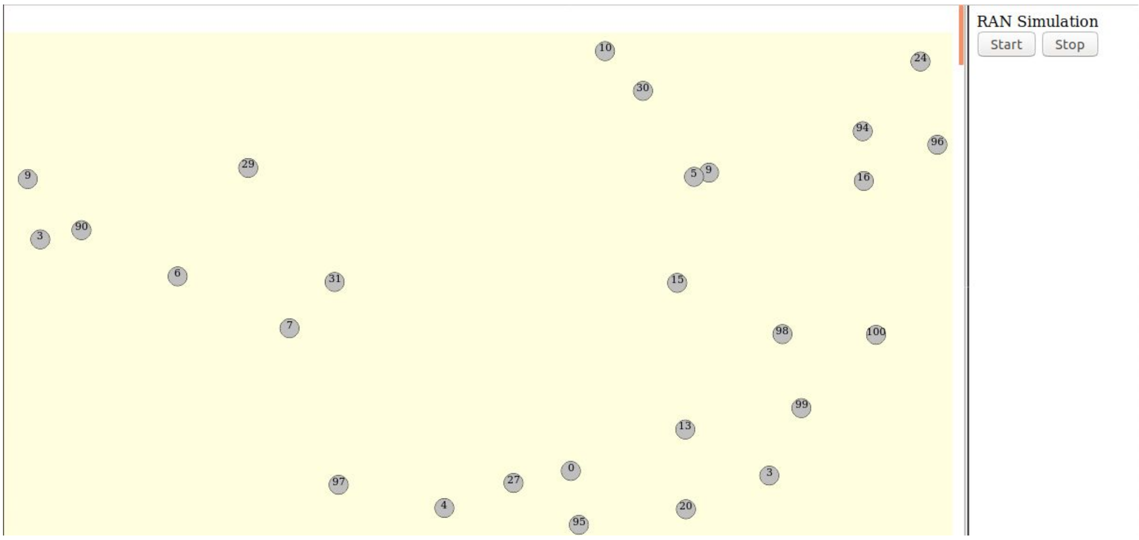


Figure 2.5 Final State of the Default Network after Corrections

The image above shows the network optimized, with the confusion and collisions issues cleared, the way to clear the confusion is, be sure that there is no two or more cells defined as neighbors with the same PCI, it is needed to redefine the PCI or delete the neighbor with longest distance from the cell this in order to clear and optimize the network and avoid issues as collisions for the PCI assignation.

2.3. Application of concept in a real scenario.

Looking forward in the use of the tool, we can test the concept in a real scenario network such as AT&T, in this case the San Francisco market, where is one of the most important markets for AT&T due to the boom of the technology, in the this area, the high crowed city of San Francisco, and the continuously increase of users demanding high speed internet access for all their devices.

With the purpose of test a real case scenario, it will be simulate the deploy for a new carrier in the 850 MHz, which will be focus on provide 5G service, the selected location is the union square in San Francisco, California, which is one of the most crowded and popular places in the bay area, and one of the first places to test new technologies.

Figure 2.6 San Francisco Union Square

For this propose it has been selected 63 real cells already built with LTE technology, the exercise will be to add a new carrier and optimize the PCIs for it to avoid collisions and confusion in the deploy of new carriers such as 5G technology.

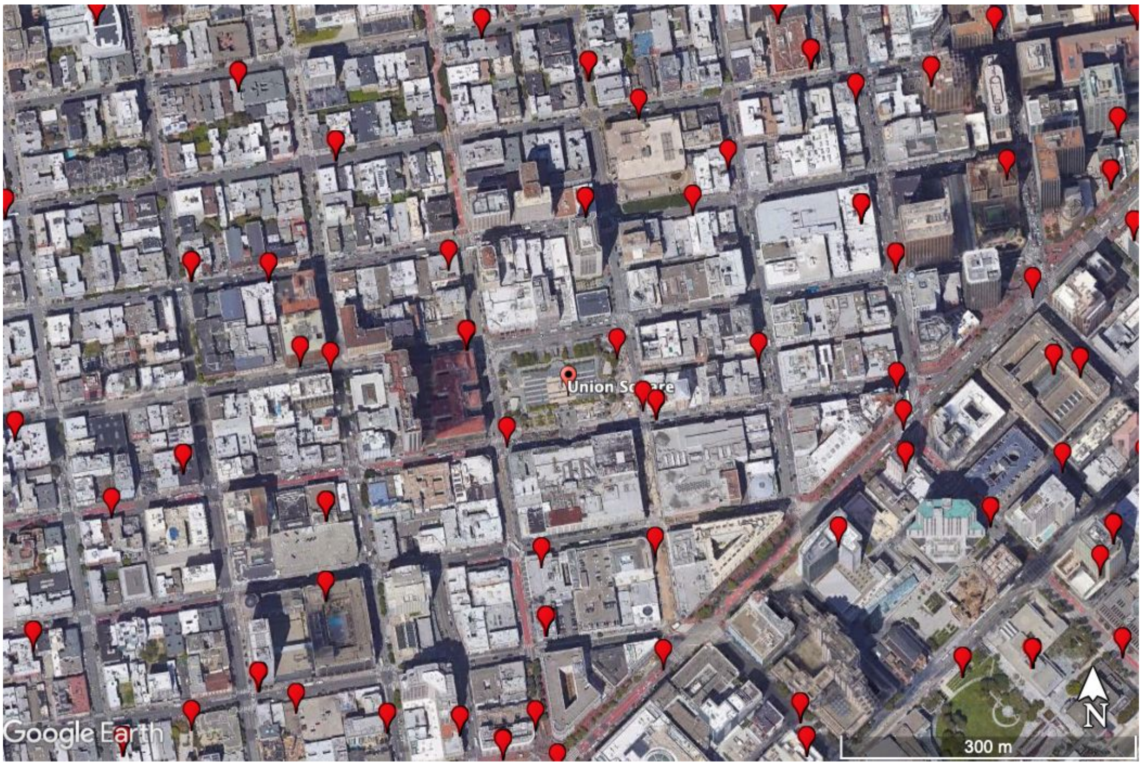


Figure 2.7 At&t Cells Around San Francisco Union Square

3. Design.

The preparation of the data either a real case scenario or a simulation, is needed to gather all the required and basic data to perform the exercise, this data can be list as coordinates, name of the cells, name of the site, and Physical Cell Identification (PCI) as minimal information needed to load the case in the RAN Simulator tool.

In order to have a design of the case, in the next chapter will be explained how the information of the network need to be prepared to work with the tool, this with the purpose to have all the information required for the exercise, and understand what kind of data from the network is needed to fulfill the purpose of this exercise.

The next three chapters can be taken as a practical manual to use RAN Simulator, due to all the steps followed to fix the presented issues in a real case scenario, has been documented, the process followed has been described, since how the information need to be ordered for the tool, in which way the information is needed for the system, how to bring up the services, how perform activities as modifications on the PCIs and edit the neighbors relations defined for each cell, until the end to confirm if remains issues on the network and how identified them.

For this exercise we will simulate a carrier aggregation dedicated for 5G service over one of the most iconic and popular plazas in San Francisco, California, the addition of a new carrier always comes with a PCI assignation plan, where sometimes can generate issues as PCI collision and PCI confusion, these issues are caused for the reusage of the PCI value defined for 1 or more cells, with a neighbor relation defined between them (X2 interface) or a interference between cells with the same PCI value, these issues will cause problems on the network for the users as drop calls during handover or low throughput to the user, and it will impact directly to the Key Performance Indicators (KPI) increasing drop calls.

This task will be executed over a software named RAN Simulator which is a software designed and created to improve this kind of issues, additional it will be use PHPmyAdmin a tool for the management of databases, this will help us to have visibility to the databases created by RAN Simulator, in order to do consultation about the number of issues on the network and confirm once all the network is optimized.

At the end of this exercise is expected a network without PCI collisions and PCI confusions, where there are no conflicts between cells and the entire network can be named as optimized regarding PCIs assignations.

3.1. Load of the network on the tool.

The steps to follow for the load, to detect issues and start the optimization will be described below, taking into account that the information as node identification, PCI, sector number and geographical coordinates are already provided, this in order to start to create the network, analyze the possible issues that can have the PCI assignation and start the optimization of the network.

Once RAN Simulator is installed and before to start the RAN Simulator service, navigate to the folder: /ransim/docker/config/ransim/ where there is a file named “sample.json” which is the file that RAN Simulator will load to create the network and all the details for each site.

Create a file following the below format, filling it with the information of the network to be created, it is important to fill in all the parameters requested by the format, once the file is complete you can replace the file located in /ransim/docker/config/ransim/ and name it as “sample.json”.

```
{
  "cellList": [
    {
      "Cell": {
        "networkId": "ran-1",
        "nodeId": "CCL00118_R01_5H_1_N",
        "physicalCellId": 11,
        "pnfName": " CCL00118",
        "sectorNumber": 0,
        "latitude": "37.7898674",
        "longitude": "-122.4011993"
      },
      "neighbor": [
        {
         "nodeId": "CCL00118_R01_5H_2_N ",
         "blacklisted": "false"
        },
        {
         "nodeId": "CCL00118_R01_5H_3_N ",
         "blacklisted": "false"
        }
      ]
    }
  ]
}
```

On the terminal, navigate to the folder ~/ran-sim/ransim/docker and start the service with the below command:

```
$ sudo docker-compose up
```

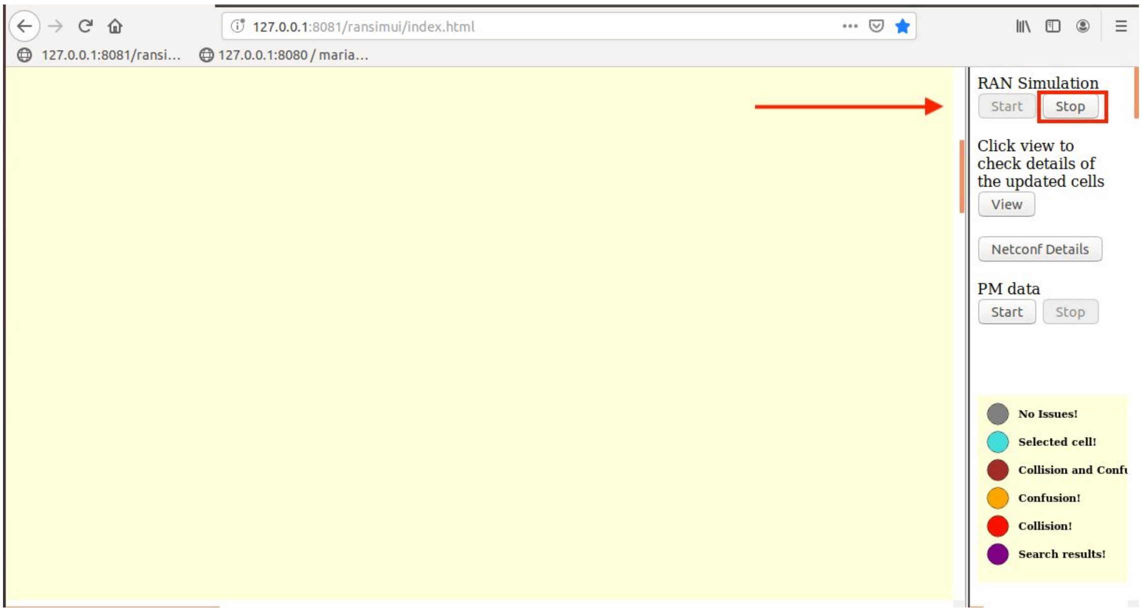
The RAN Simulator Service will start and you will be able to access to the next URLs:

RAN Simulator: http://127.0.0.1:8081/ransimui/index.html

PHP My Admin: http://127.0.0.1:8080/index.php

3.2. Use RAN Simulator tool.

Go into RAN Simulator with the URL and press the stop button located to the top right of the web page. This in order to stop all previous processes.

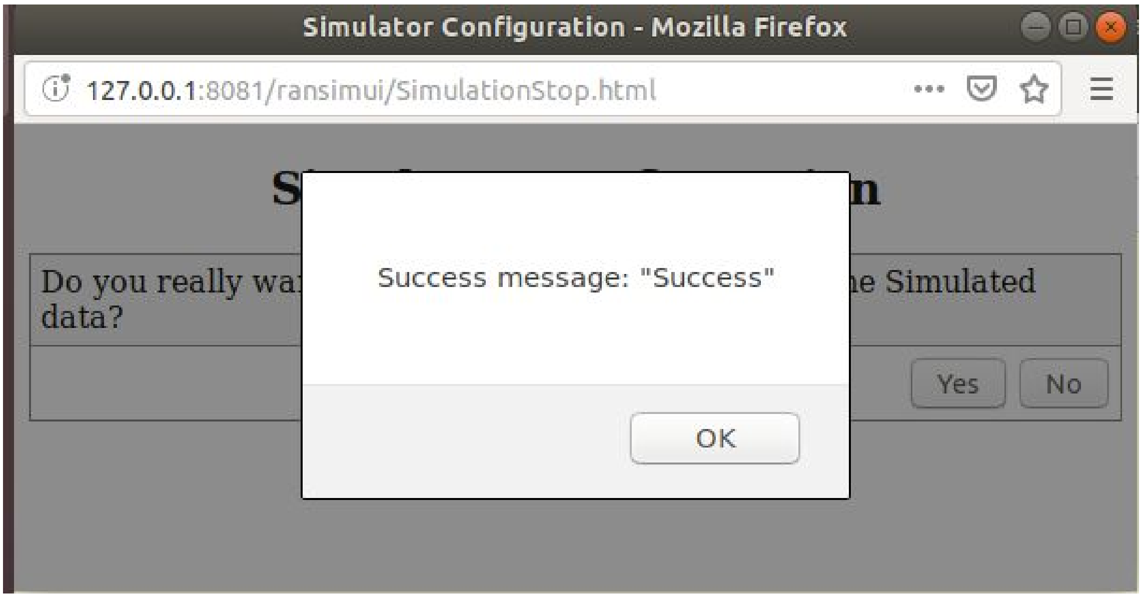


Click view to check details of the updated cells

Figure 3.1 General View of RAN Simulator

A window with a message will come up asking, “Do you really want to stop the Simulation and clear the Simulated data?”, click on “Yes” to clear all the previous loaded data.

A message will pop up with the message, “Success”, this will confirm that all previous process has been stopped.


Simulator Configuration - Mozilla Firefox
127.0.0.1:8081/ransimui/SimulationStop.html
OK
Yes
No

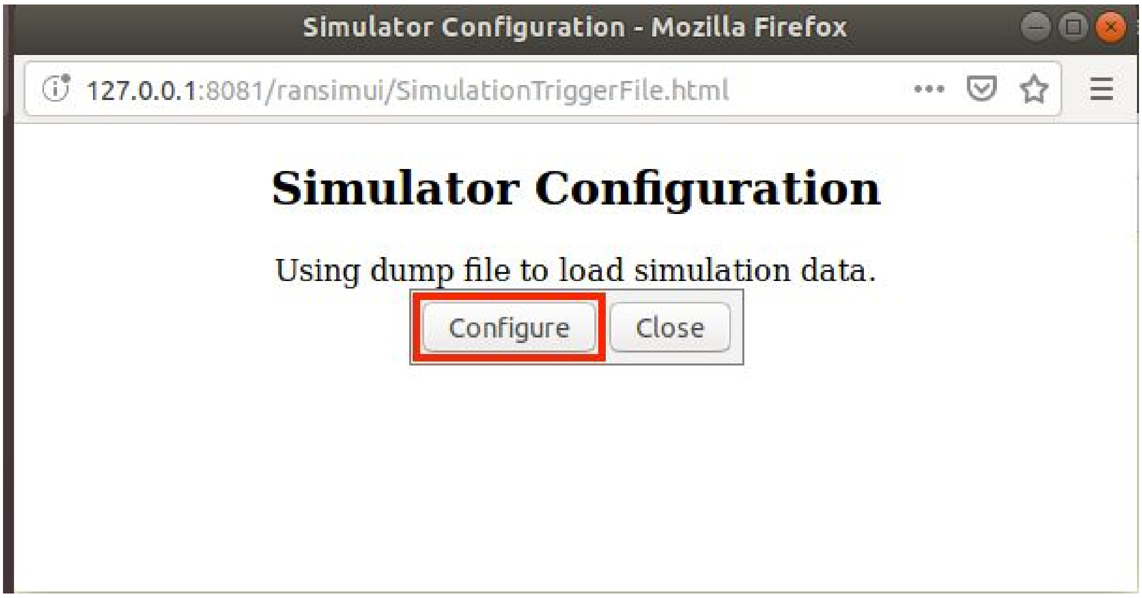
Do you really wa
data?

he Simulated

Success message: "Success"

Figure 3.2 Success Message after Stop Previous Work

Then Press the “Start” button in the main menu of RAN Simulator, a new message will come up confirming that the system is ready for the load of the data, and the network configuration saved, press “Configure” to load the network data.



Simulator Configuration - Mozilla Firefox

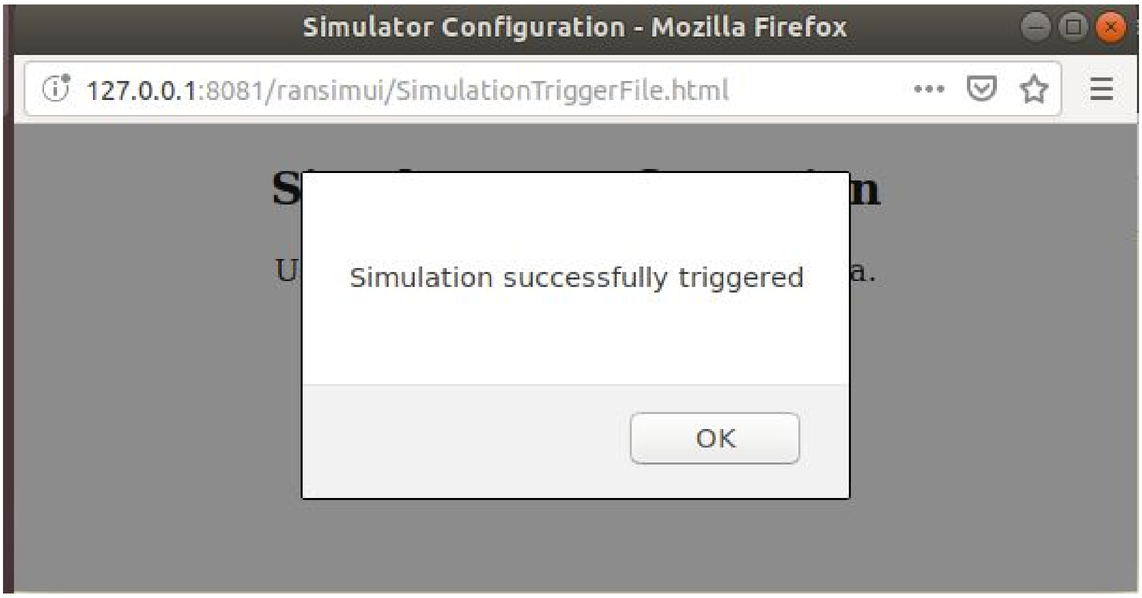
127.0.0.1:8081/ransimui/SimulationTriggerFile.html

Simulator Configuration

Using dump file to load simulation data.

Figure 3.3 Start Menu for load a new Network

It will take a few seconds, then a message confirming the successful load of the network will appear.



Simulator Configuration - Mozilla Firefox

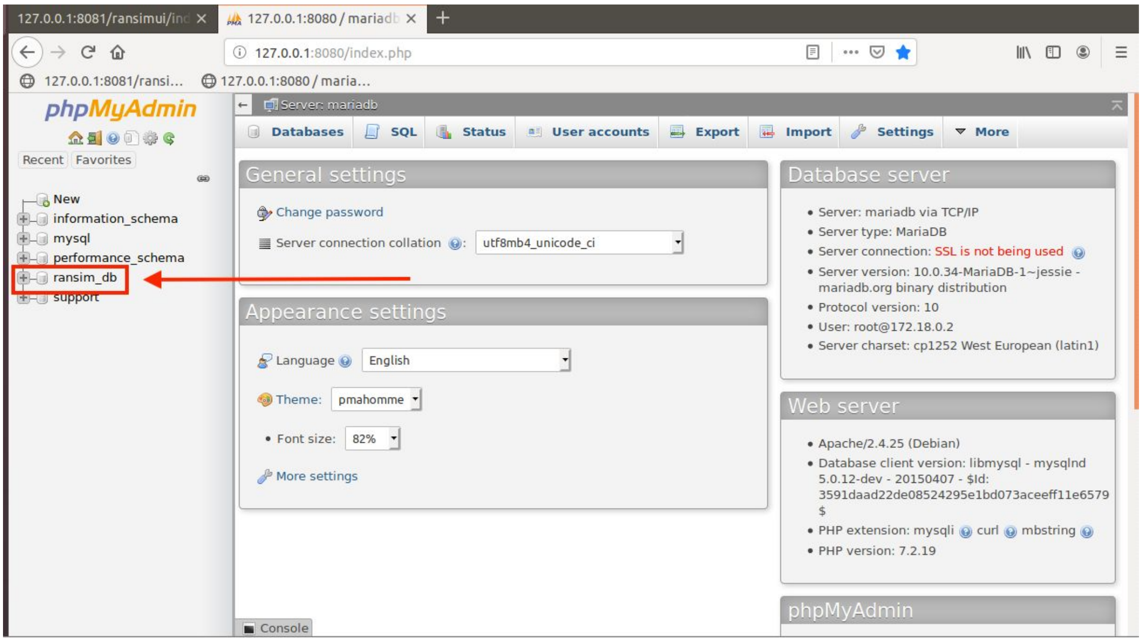
127.0.0.1:8081/ransimui/SimulationTriggerFile.html

Simulation successfully triggered

Figure 3.4 Success Message after load Network Data

Refresh the RAN Simulator web page and in a new tap, get access to PHP my Admin http://127.0.0.1:8080/index.php, using the credentials: Username: “root” and Password: “secret”. This in order to have access to the database created and confirm the correct load of the data network.

Inside PHP my Admin, it is needed to get access to the database created by RAN Simulator, this can be found in the left side with the name “ransim_db”, click on it to have access to this database.



General settings

- Change password
- Server connection collation: utf8mb4_unicode_ci

Appearance settings

- Language: English
- Theme: pmahomme
- Font size: 82%
- More settings

Database server

- Server: mariadb via TCP/IP
- Server type: MariaDB
- Server connection: SSL is not being used
- Server version: 10.0.34-MariaDB-1~jessie - mariadb.org binary distribution
- Protocol version: 10
- User: root@172.18.0.2
- Server charset: cp1252 West European (latin1)

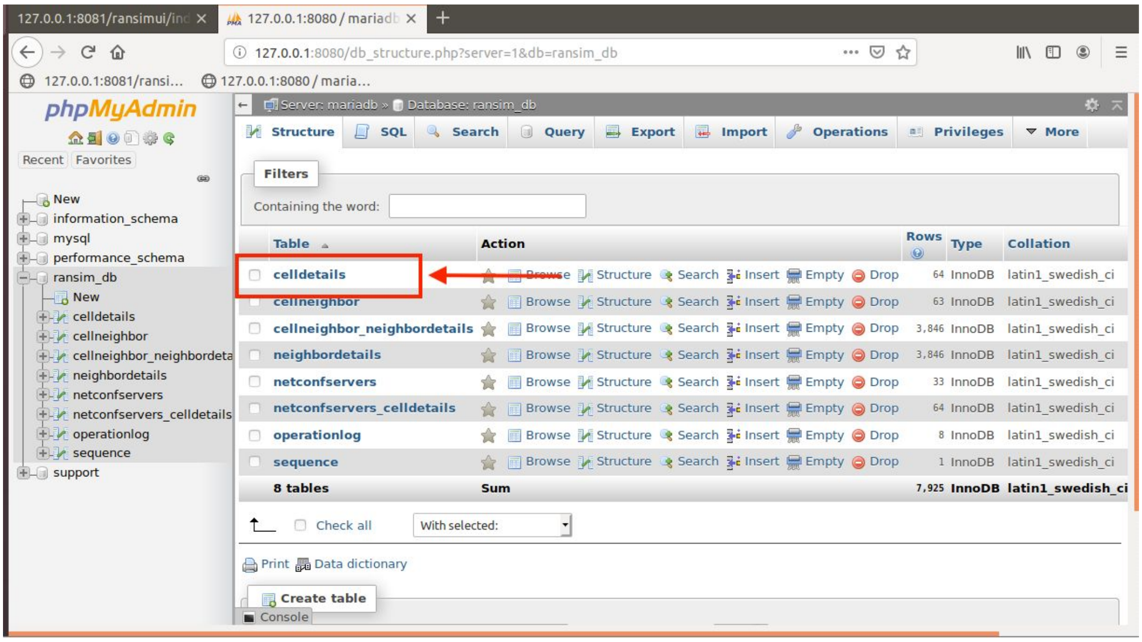
Web server

- Apache/2.4.25 (Debian)
- Database client version: libmysql - mysqlnd 5.0.12-dev - 20150407 - $Id: 3591daad22de08524295e1bd073aceeff11e6579 $
- PHP extension: mysqli curl mbstring
- PHP version: 7.2.19

phpMyAdmin

Figure 3.5 Main Menu of PHP my Admin

Inside “ransim_db” you will find tables with the information of the network created by RAN Simulator, to check if all the data that we upload to the tool is correctly loaded, it is needed to have access to “celldetails” table, where it will be all the data and details of the network.



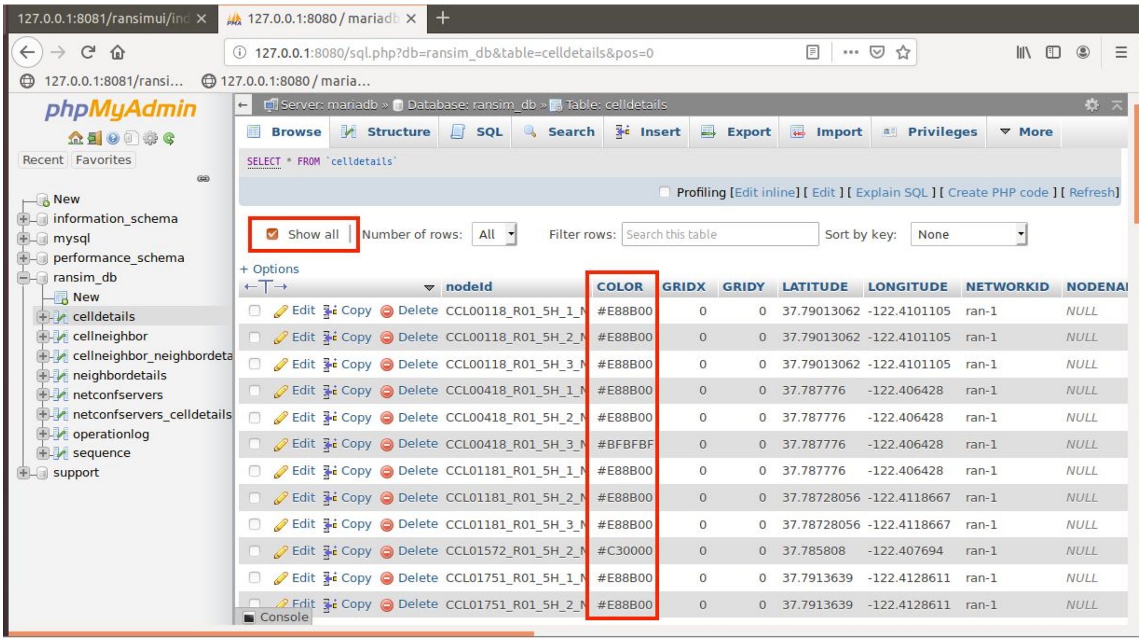
Containing the word:

Table	Action						Rows	Type	Collation
celldetails	Browse	Structure	Search	Insert	Empty	Drop	64	InnoDB	latin1_swedish_ci
cellneighbor	Browse	Structure	Search	Insert	Empty	Drop	63	InnoDB	latin1_swedish_ci
cellneighbor_neighbordetails	Browse	Structure	Search	Insert	Empty	Drop	3,846	InnoDB	latin1_swedish_ci
neighbordetails	Browse	Structure	Search	Insert	Empty	Drop	3,846	InnoDB	latin1_swedish_ci
netconfservers	Browse	Structure	Search	Insert	Empty	Drop	33	InnoDB	latin1_swedish_ci
netconfservers_celldetails	Browse	Structure	Search	Insert	Empty	Drop	64	InnoDB	latin1_swedish_ci
operationlog	Browse	Structure	Search	Insert	Empty	Drop	8	InnoDB	latin1_swedish_ci
sequence	Browse	Structure	Search	Insert	Empty	Drop	1	InnoDB	latin1_swedish_ci
8 tables	Sum						7,925	InnoDB	latin1_swedish_ci

With selected:

Figure 3.6 List of Tables created by RAN Simulator

Inside the “datadetails” table, click on the option “Show all” and then confirm if all the cells have been assigned a color, in the “COLOR” table, this mean that for each cell a state has been defined, and it can be process and modified on the RAN Simulator tool.



```
SELECT * FROM `celldetails`
```

□ Profiling [Edit inline] [Edit] [Explain SQL] [Create PHP code] [Refresh]

☑ Show all | Number of rows: All | Filter rows: Search this table | Sort by key: None

+ Options

	nodeId	COLOR	GRIDX	GRIDY	LATITUDE	LONGITUDE	NETWORKID	NODENAI
□ Edit Copy Delete	CCL00118_R01_5H_1_N	#E88B00	0	0	37.79013062	-122.4101105	ran-1	NULL
□ Edit Copy Delete	CCL00118_R01_5H_2_N	#E88B00	0	0	37.79013062	-122.4101105	ran-1	NULL
□ Edit Copy Delete	CCL00118_R01_5H_3_N	#E88B00	0	0	37.79013062	-122.4101105	ran-1	NULL
□ Edit Copy Delete	CCL00418_R01_5H_1_N	#E88B00	0	0	37.787776	-122.406428	ran-1	NULL
□ Edit Copy Delete	CCL00418_R01_5H_2_N	#E88B00	0	0	37.787776	-122.406428	ran-1	NULL
□ Edit Copy Delete	CCL00418_R01_5H_3_N	#BFBFBF	0	0	37.787776	-122.406428	ran-1	NULL
□ Edit Copy Delete	CCL01181_R01_5H_1_N	#E88B00	0	0	37.787776	-122.406428	ran-1	NULL
□ Edit Copy Delete	CCL01181_R01_5H_2_N	#E88B00	0	0	37.78728056	-122.4118667	ran-1	NULL
□ Edit Copy Delete	CCL01181_R01_5H_3_N	#E88B00	0	0	37.78728056	-122.4118667	ran-1	NULL
□ Edit Copy Delete	CCL01572_R01_5H_2_N	#C30000	0	0	37.785808	-122.407694	ran-1	NULL
□ Edit Copy Delete	CCL01751_R01_5H_1_N	#E88B00	0	0	37.7913639	-122.4128611	ran-1	NULL
□ Edit Copy Delete	CCL01751_R01_5H_2_N	#E88B00	0	0	37.7913639	-122.4128611	ran-1	NULL

Figure 3.7 Elements of the Network loaded by RAN Simulator

Then back to RAN Simulator, you will be able to see the cells loaded and with colors identifying their status as: grey: “No Issues”, blue: “Selected cell”, deep red: “Collision and Confusion”, yellow: “Confusion”, red: “Collision”, purple: “Search results”. These colors will help to identify which issues have every cell to solve and avoid issues on the network.

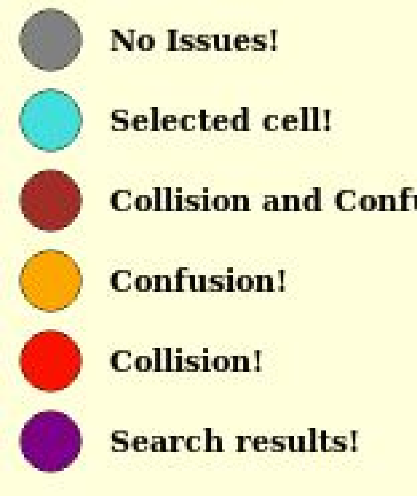


Figure 3.8 Color Code for Status of Cells on RAN Simulator

Pressing right click over a cell a menu will appear, with the management option for each cell:

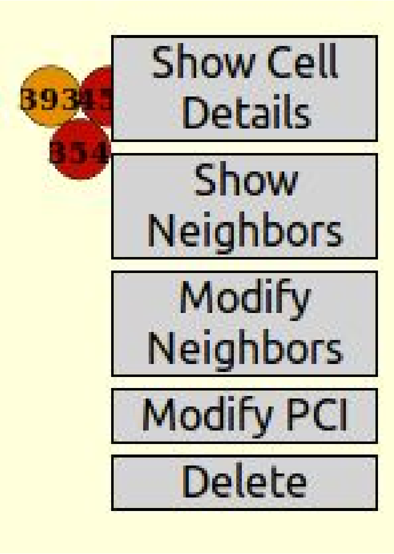
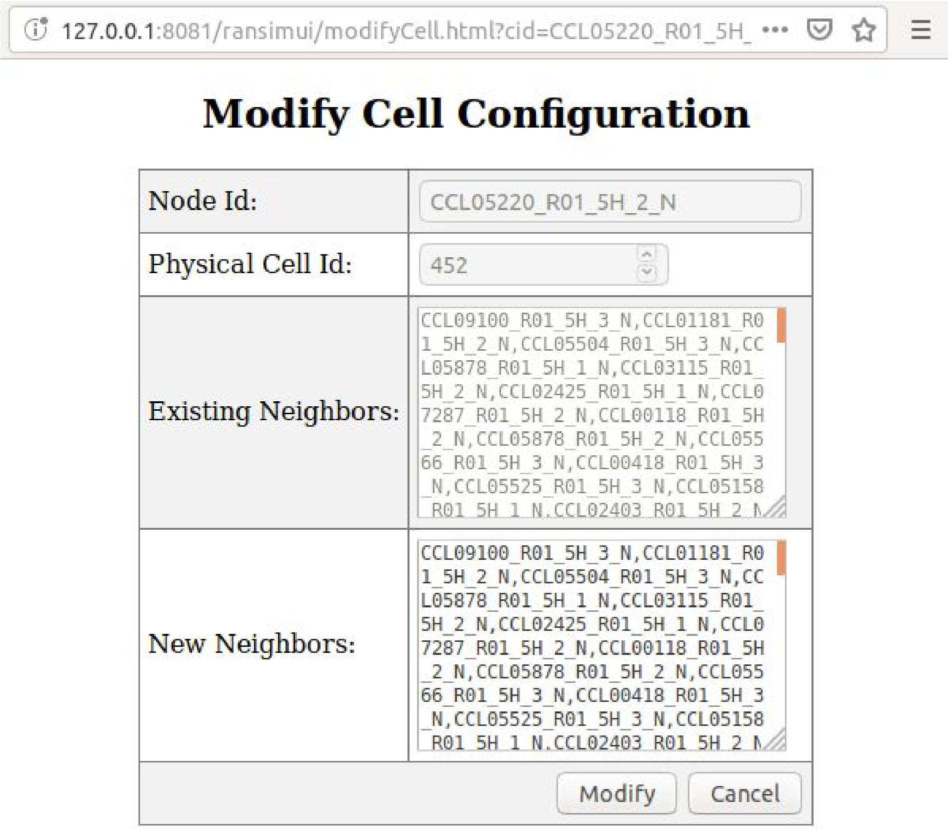


Figure 3.9 Right Click Menu of a Cell on RAN Simulator

“Show Cell Details”: a message will come up with cell details as “Node Id”, “Physical Cell Id” and “Pnf Name” this menu is not editable.

“Show Neighbors”: This will show lines representing X2 interfaces, pointing the cells with a neighbor relation defined for this cell and displaying colors marking if there is an issue generated for a relation, green: “No Issue”, red: “Collision”, yellow: “Confusion”.

“Modify Neighbors”: This will show a menu where it is possible add or delete neighbors for the selected cell.



127.0.0.1:8081/ransimui/modifyCell.html?cid=CCL05220_R01_5H_

Modify Cell Configuration

Node Id:	CCL05220_R01_5H_2_N
Physical Cell Id:	452
Existing Neighbors:	CCL09100_R01_5H_3_N,CCL01181_R01_5H_2_N,CCL05504_R01_5H_3_N,CCL05878_R01_5H_1_N,CCL03115_R01_5H_2_N,CCL02425_R01_5H_1_N,CCL07287_R01_5H_2_N,CCL00118_R01_5H_2_N,CCL05878_R01_5H_2_N,CCL05566_R01_5H_3_N,CCL00418_R01_5H_3_N,CCL05525_R01_5H_3_N,CCL05158_R01_5H_1_N,CCL02403_R01_5H_2_N
New Neighbors:	CCL09100_R01_5H_3_N,CCL01181_R01_5H_2_N,CCL05504_R01_5H_3_N,CCL05878_R01_5H_1_N,CCL03115_R01_5H_2_N,CCL02425_R01_5H_1_N,CCL07287_R01_5H_2_N,CCL00118_R01_5H_2_N,CCL05878_R01_5H_2_N,CCL05566_R01_5H_3_N,CCL00418_R01_5H_3_N,CCL05525_R01_5H_3_N,CCL05158_R01_5H_1_N,CCL02403_R01_5H_2_N

Figure 3.10 "Modify Neighbor" Menu on RAN Simulator

“Modify PCI”: This will show a window where the PCI value can be change for the selected Cell.

“Delete”: This is for erase the cell and all details related to it.

4. Development.

To the development of the exercise of solving the issues presented by the example network, in the next chapter will be explain how to fix these issues, as PCI collision and confusion, describing the two principal ways to fix them and the consequences of it.

In order to clear all the issues presented, is needed to repeat the below explained process to each cell until the issues are clear, following the described methods and taking into account the neighbors cells, due to all of them works along with all the cells, so it can be say that the actions taken to one cell would affect the neighbors or the entire network.

4.1. Optimizing the Network.

To start the optimization of the network, it is important to identify the cells with marked issues. RAN Simulator has marked the cells according with the network information provided and marked each one with a color, which represents the issues found, these cells are the ones that most be corrected in order to improve the network.

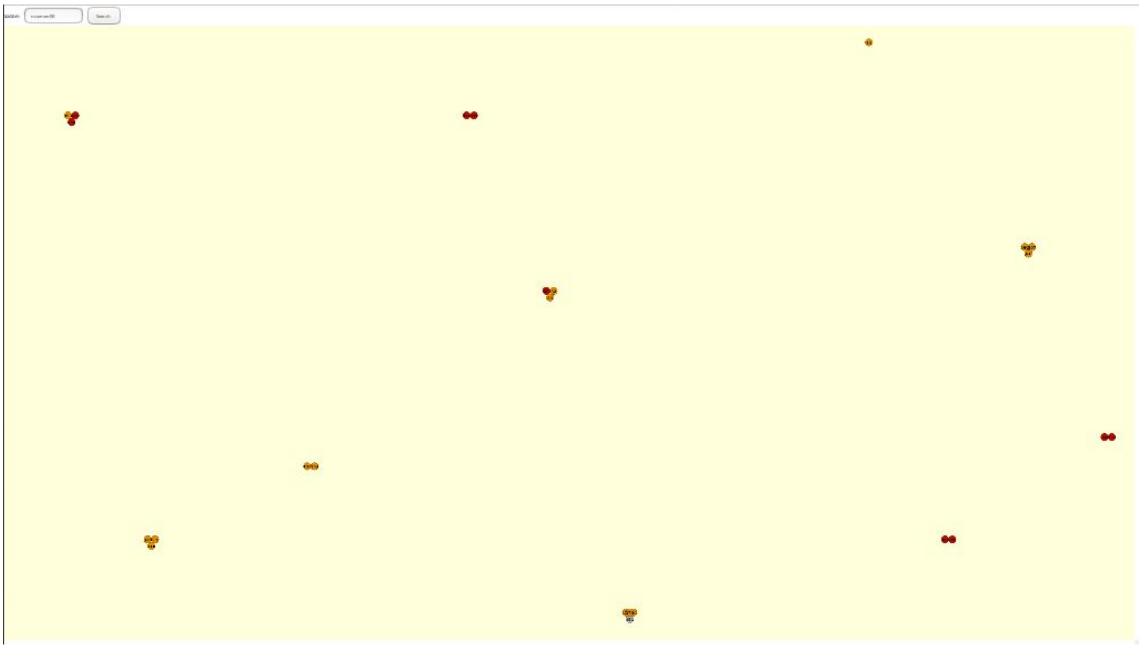


Figure 4.1 First state of the Real Scenario Network

For this exercise, we will start solving the sites marked with deep red “collision and confusion”, this in order to start to clear the issues.

4.2. Solving PCI Collision Issue.

Starting with the site CCL05504_R01_5H_3_N, which is marked in deep red, we will be able to see the defined neighbors and marked in red the ones the cells generating issues to the selected cell

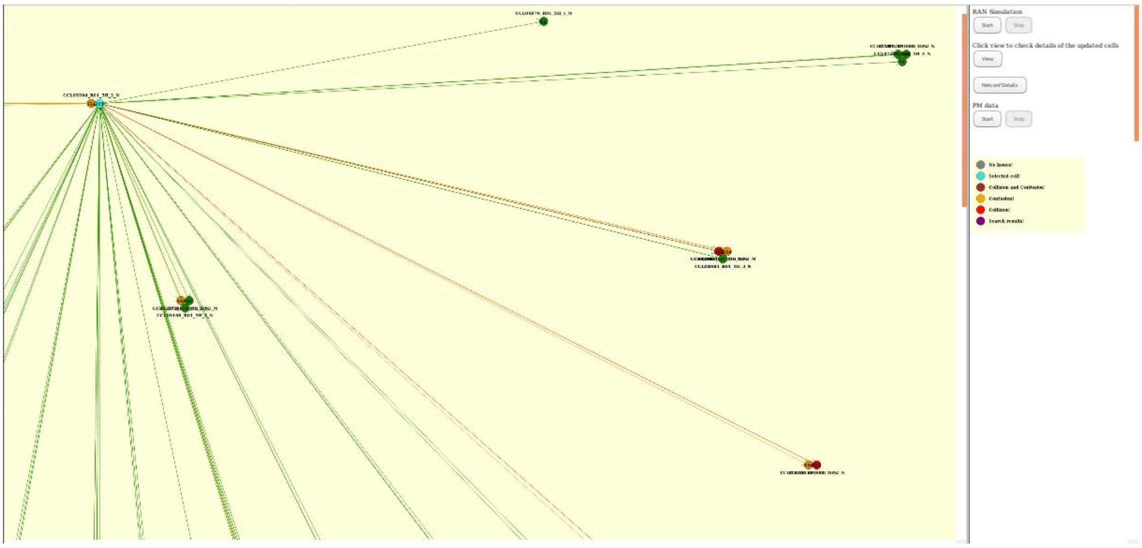


Figure 4.2 Cell with Collision issue showing neighbors relations

In the image above we are able to see the cells generating issues to the cell CCL05504_R01_5H_3_N, to solve the issues generated it can be done in two ways:

- Delete the neighbor from the neighbors list: This will cause drop calls during the handovers and has a direct impact to the KPIs, it is not recommended if the cell is close enough due to the high probability of receive or send a hand over to that cell.

- PCI reassignation: This work follows up the rules of the PCI assignation, depending of the PCI plan and usage of the assigned carrier, and not using a PCI already in use close to the cell with the issue, this can generate a new collision or confusion in the neighbor cells

Each case is different; that is why it is needed to evaluate the situation, according with the impact of the change, erase the neighbor of the list or change the PCI.

For this first cases, due to the short distance from the cell we will do a PCI reassignation.

To assign new PCI is needed to follow up rules about PCIs distribution: the range for PCIs are from 0 to 503, and due to the PCI is assigned for sector and by site, the assignation must be consecutive example: 159 for sector alpha, 160 for sector beta and 161 for sector gamma.

After the PCI reassignation for sectors: CCL05504_R01_5H_3_N and CCL05504_R01_5H_2_N the colors have changed, meaning that the issue of collision and confusion has been solved for this case.

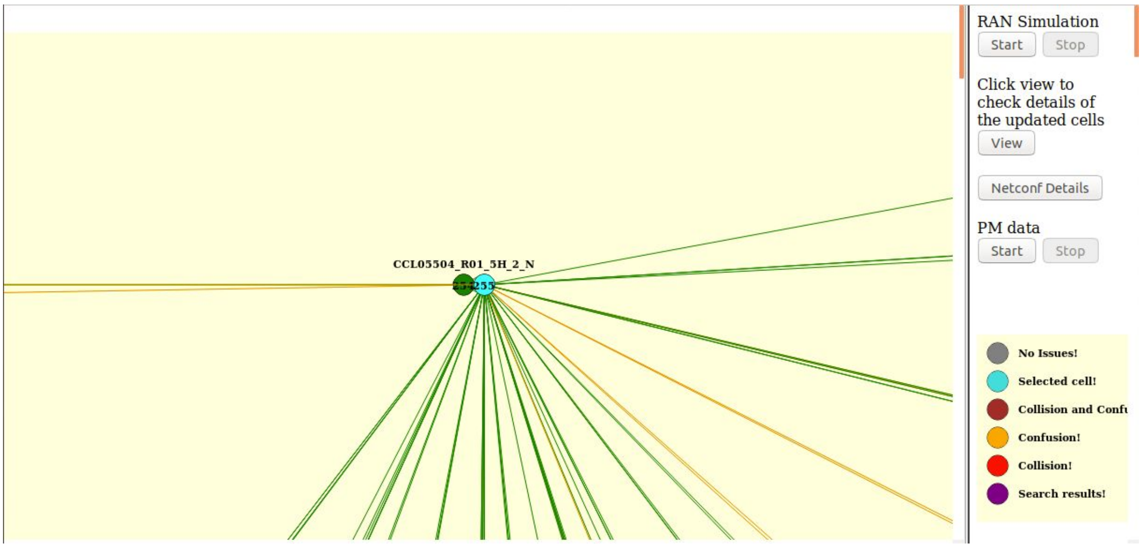


Figure 4.3 Cell After PCI reassignation

it is needed to repeat the above process to solve the collision issues marked on the network, until clear all the cells of the collision issue.

4.3. Solving Confusion issue.

For confusion issue, also can be solved reassigning PCI or erase strategic neighbors defined for a cell with issues.

For this case we will show the process of erase neighbors relations. To erase a specific neighbor, it is needed to take into consideration that erasing a already defined neighbor, the selected cell will not be able to do a handover to the deleted cell, this solution can be applied, if the distance between the selected cells is considerable and on the condition that there are cells between them, which can do a handover to the cell with issue.

For cell CCL01751_R01_5H_2_N marked in a blue square, which has a confusion issue with cell CCL00418_R01_5H_3_N marked on red, for this case it is valid erase this neighbor relation, due to between these two cells, are cells with neighbors relation defined from CCL01751_R01_5H_2_N, these mentioned neighbors relations defined can handle the handovers from cell CCL01751_R01_5H_2_N, and the relation between the two cells with confusion issues can be erase, expecting no impact to the performance of the network.

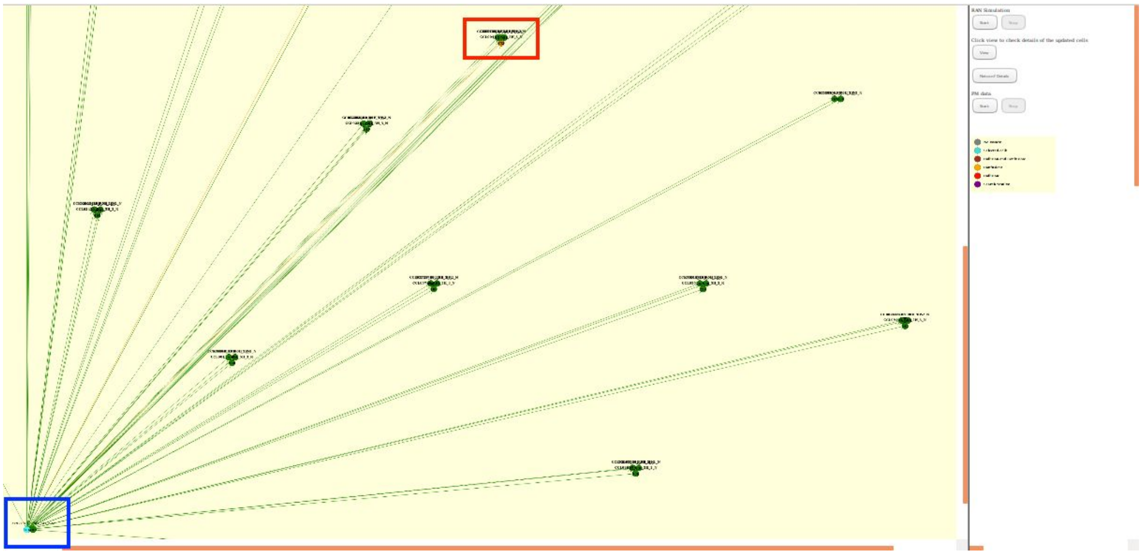
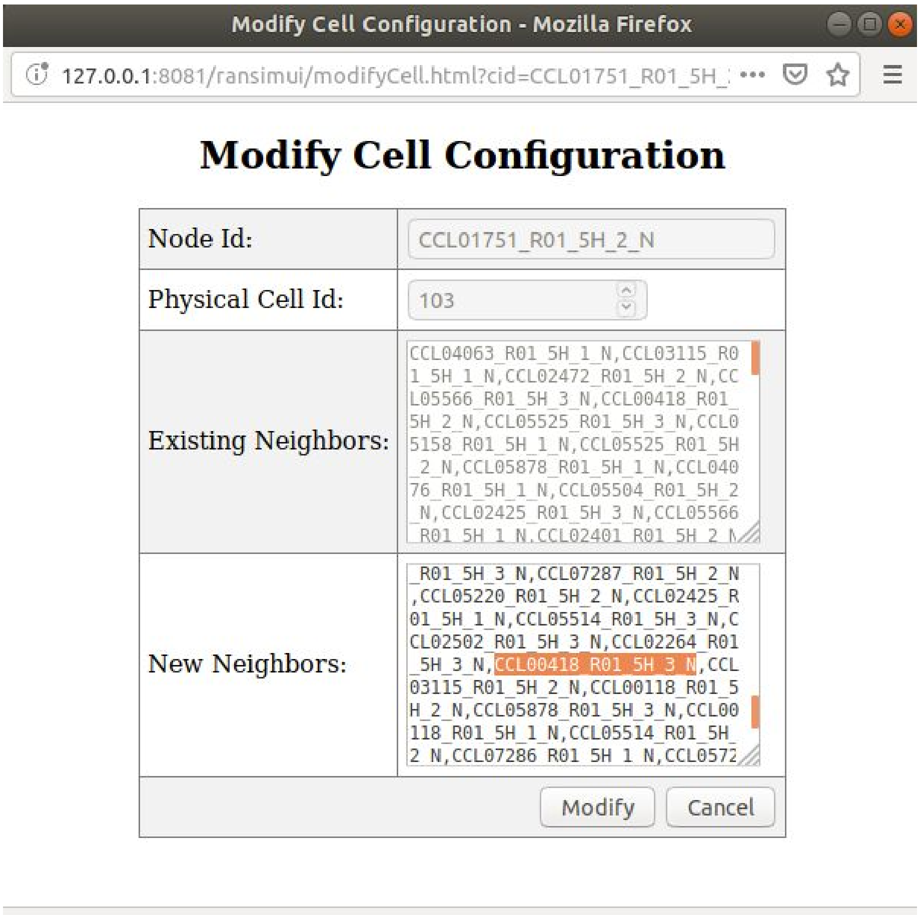


Figure 4.4 Cell with Confusion issue showing Neighbors relations

To delete the defined neighbor relation, do right click on the source cell and select “Modify Neighbors” find the cell to erase in the neighbors list, delete it from the list and click on “Modify” to save the changes.

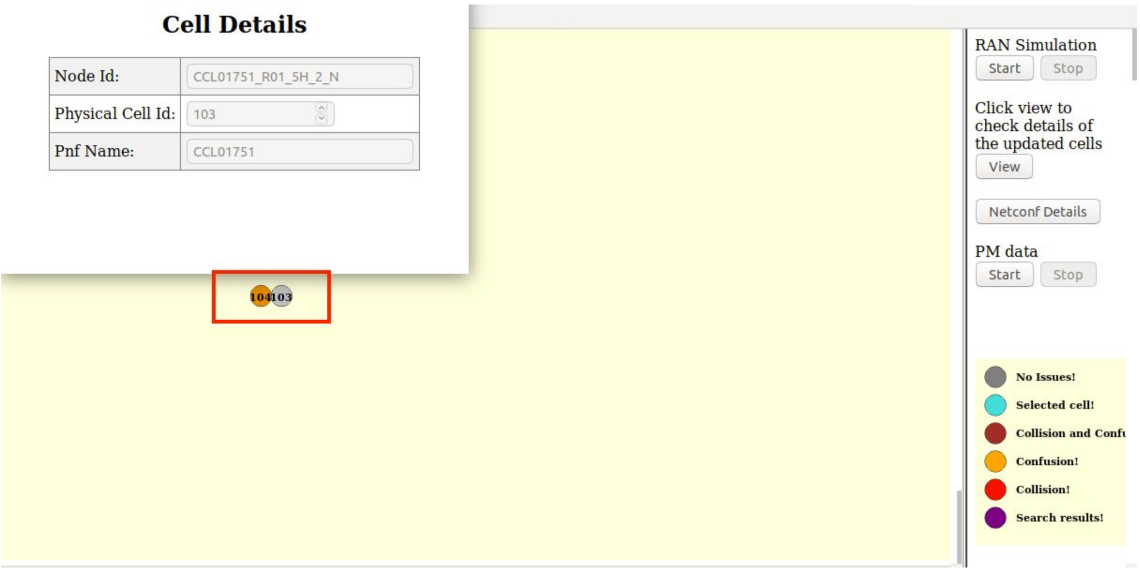

Modify Cell Configuration - Mozilla Firefox
127.0.0.1:8081/ransimui/modifyCell.html?cid=CCL01751_R01_5H_

Modify Cell Configuration

Node Id:	CCL01751_R01_5H_2_N
Physical Cell Id:	103
Existing Neighbors:	CCL04063_R01_5H_1_N,CCL03115_R01_5H_1_N,CCL02472_R01_5H_2_N,CCL05566_R01_5H_3_N,CCL00418_R01_5H_2_N,CCL05525_R01_5H_3_N,CCL05158_R01_5H_1_N,CCL05525_R01_5H_2_N,CCL05878_R01_5H_1_N,CCL04076_R01_5H_1_N,CCL05504_R01_5H_2_N,CCL02425_R01_5H_3_N,CCL05566_R01_5H_1_N,CCL02401_R01_5H_2_N
New Neighbors:	_R01_5H_3_N,CCL07287_R01_5H_2_N,CCL05220_R01_5H_2_N,CCL02425_R01_5H_1_N,CCL05514_R01_5H_3_N,CCL02502_R01_5H_3_N,CCL02264_R01_5H_3_N,CCL00418_R01_5H_3_N,CCL03115_R01_5H_2_N,CCL00118_R01_5H_2_N,CCL05878_R01_5H_3_N,CCL00118_R01_5H_1_N,CCL05514_R01_5H_2_N,CCL07286_R01_5H_1_N,CCL0572

Figure 4.5 "Modify Neighbors" Menu

If the cell has no more issues it will turn to gray color, meaning that there are not any other issue and this cell is clear, as can be see in the below image.



Cell Details

Node Id:	CCL01751_R01_5H_2_N
Physical Cell Id:	103
Pnf Name:	CCL01751

Figure 4.6 Cell After Clear PCI Collision and Confusion

The rest of the cells can be optimized on the same two ways explained before, this method can be done, until all the cell shows the status of no issues, meaning that the network is free of collision and confusions regarding PCI assignation and neighbors relations definition.

Validation after the tasks of clear collisions and confusion.

After the usage of the tools provided by RAN Simulator to solve the issues presented at the beginning of the case, we can confirm if the issues have been solved, and the tool work, after follow the process mentioned before to clear issues as PCI collisions and confusions, in the next chapter we will confirm and see how the tool shows a network without mentioned issues, ready to upload or export as a optimized network regarding PCI assignation.

The validation of the work performed on the RAN Simulator tool, can be confirm in the next chapter, where using tools as access to the database created by the system, we can confirm the number of issues for each cell, and double check the correct functioning of the Software.

A Network without PCI Collision and Confusion issues.

The RAN Simulator tool once all the sectors are free of PCI collision and confusion, will show the entire cells of the network in gray color, meaning the sectors has no issues between them, there are two ways to confirm the network has been cleared of issues.

All the cells shown are on gray color, and the lines represented the X2 interface by the function “Show Neighbors” are in green, meaning that all cells have been optimized and has no issues to correct.

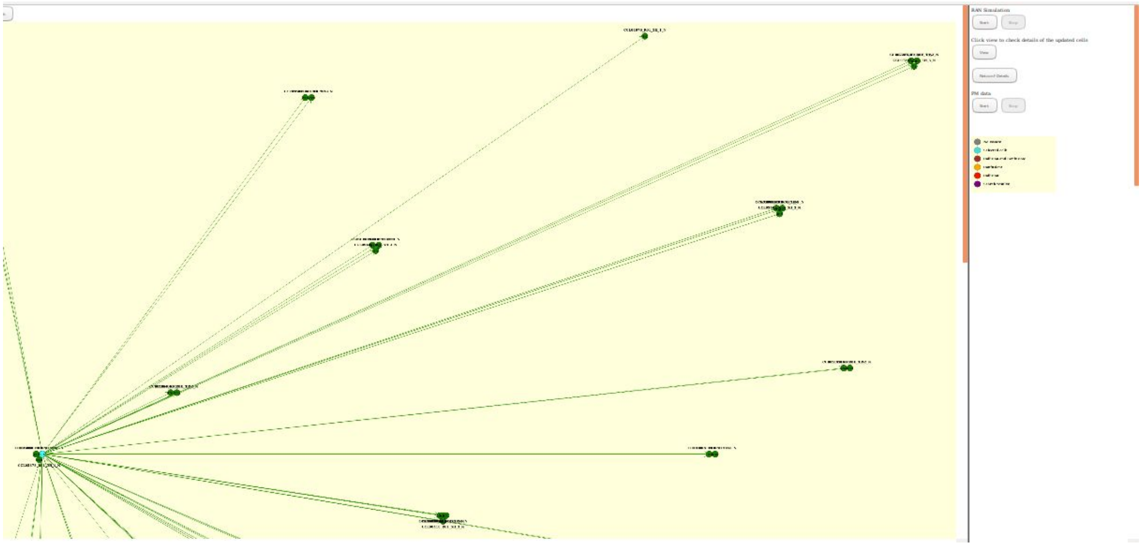
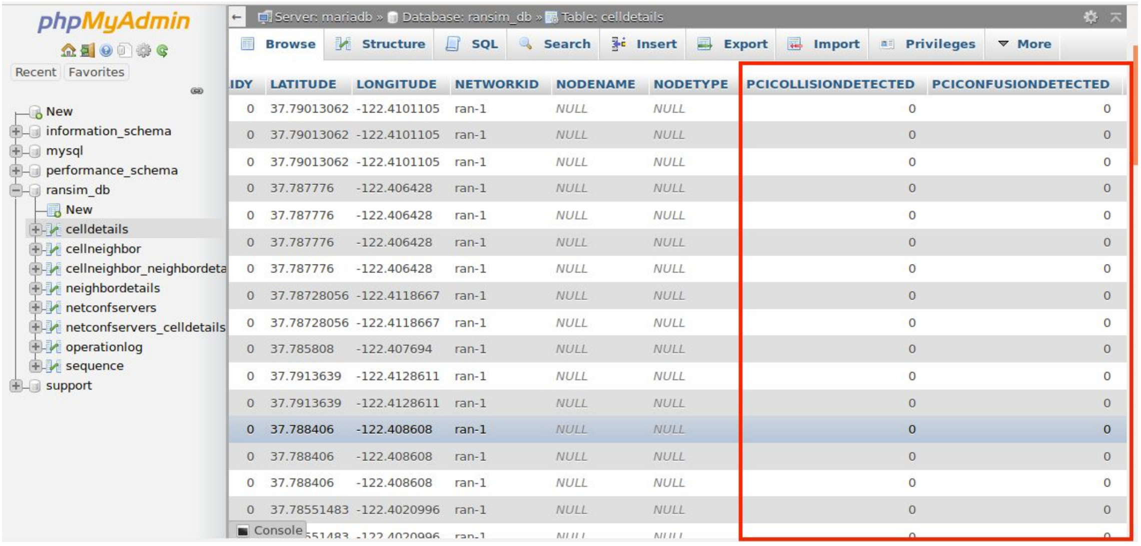


Figure 5.1 Network After Clear PCI Collision and Confusion

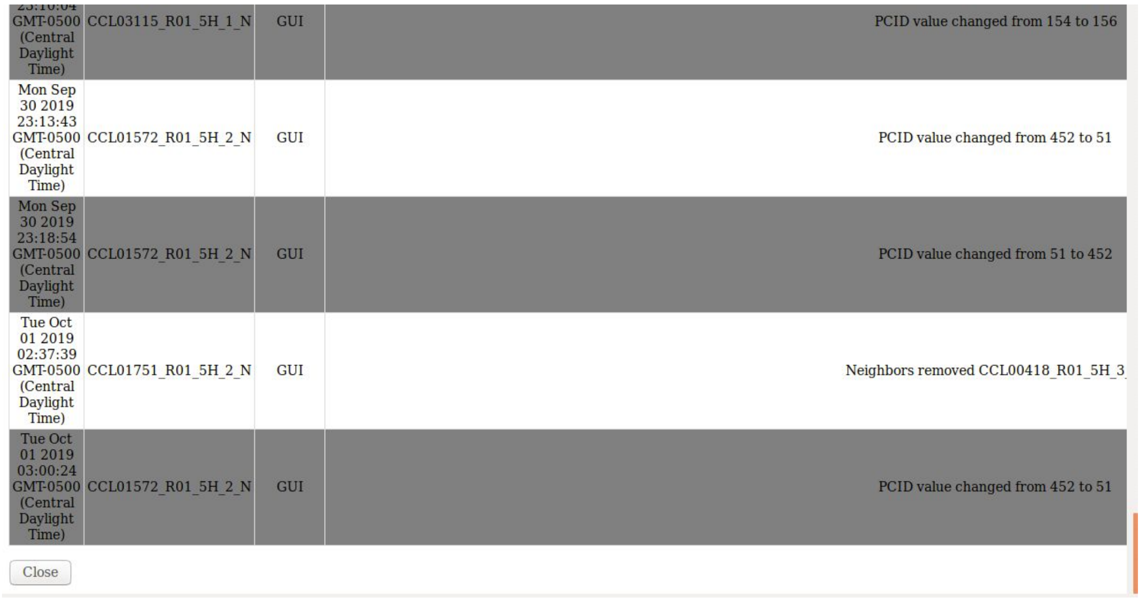
Get access to PHP my Admin, in the database created by RAN Simulator named ransim_db, in the table “sitedetails” there are two columns with the names “PCICOLLISIONDETECTED” and “PCICONFUSIONDETECTED” these columns will show the number of issues encountered in the network, if these two columns show 0 in all fields, the tool hasn’t found any issue regarding PCIs.



IDY	LATITUDE	LONGITUDE	NETWORKID	NODENAME	NODETYPE	PCICOLLISIONDETECTED	PCICONFUSIONDETECTED
0	37.79013062	-122.4101105	ran-1	NULL	NULL	0	0
0	37.79013062	-122.4101105	ran-1	NULL	NULL	0	0
0	37.79013062	-122.4101105	ran-1	NULL	NULL	0	0
0	37.787776	-122.406428	ran-1	NULL	NULL	0	0
0	37.787776	-122.406428	ran-1	NULL	NULL	0	0
0	37.787776	-122.406428	ran-1	NULL	NULL	0	0
0	37.787776	-122.406428	ran-1	NULL	NULL	0	0
0	37.78728056	-122.4118667	ran-1	NULL	NULL	0	0
0	37.78728056	-122.4118667	ran-1	NULL	NULL	0	0
0	37.785808	-122.407694	ran-1	NULL	NULL	0	0
0	37.7913639	-122.4128611	ran-1	NULL	NULL	0	0
0	37.7913639	-122.4128611	ran-1	NULL	NULL	0	0
0	37.788406	-122.408608	ran-1	NULL	NULL	0	0
0	37.788406	-122.408608	ran-1	NULL	NULL	0	0
0	37.788406	-122.408608	ran-1	NULL	NULL	0	0
0	37.78551483	-122.4020996	ran-1	NULL	NULL	0	0
	551483	-122.4020996	ran-1	NULL	NULL	0	0

Figure 5.2 Table showing no issues encountered on the network

To keep track of all the changes made in the network, RAN Simulator is saving all the changes in a log, this can be consulted any time in the main menu in the right section, with the button “view” this will trigger a different window where all the changes can be consulted this in order to keep track of the modifications performed on the network.



23:10:04 GMT-0500 (Central Daylight Time)	CCL03115_R01_5H_1_N	GUI	PCID value changed from 154 to 156
Mon Sep 30 2019 23:13:43 GMT-0500 (Central Daylight Time)	CCL01572_R01_5H_2_N	GUI	PCID value changed from 452 to 51
Mon Sep 30 2019 23:18:54 GMT-0500 (Central Daylight Time)	CCL01572_R01_5H_2_N	GUI	PCID value changed from 51 to 452
Tue Oct 01 2019 02:37:39 GMT-0500 (Central Daylight Time)	CCL01751_R01_5H_2_N	GUI	Neighbors removed CCL00418_R01_5H_3
Tue Oct 01 2019 03:00:24 GMT-0500 (Central Daylight Time)	CCL01572_R01_5H_2_N	GUI	PCID value changed from 452 to 51

Figure 5.3 List of changes performed on the network

5. Acronyms.

API	Application Program Interface
CPRI	Common Public Radio Interface
ENODEB	Evolved Node B
IP	Internet Protocol
KPI	Key Performance Indicator
LTE	Long Term Evolution
NFV	Network function virtualization
ONAP	Open Network Automation Platform
PCI	Physical Cell ID
PNF	Physical Network Function
PSS	Primary Synchronization Signal
RAN	Radio Access Network
SDK	Software Development Kit
SON	Self-Organizing Network
SSS	Secondary Synchronization signal
UE	User Equipment
VNF	Virtualized Network Function

6. Bibliography.

[1] Choi, S., Song, J., Kim, J., Lim, S., Choi, S., Kwon, T. T., & Bahk, S. (2019). 5G K-SimNet: End-to-End Performance Evaluation of 5G Cellular Systems.https://doi.org/10.1109/CCNC.2019.8651686.

[2] Ericsson Telefonica. (2015). Cloud RAN Architecture for 5G, 1–24. Retrieved from:

http://www.tid.es/sites/526e527928a32d6a7400007f/content_entry5321ef0928a32d08900000ac/578f4eda1146dde411001d0e/files/WhitePaper_C-RAN_for_5G_-_In_collab_with_Ericsson_SC_-_quotes_-_FINAL.PDF.

[3] Huawei, E. (2018). PCI confusions vs. PCI collisions, (0). Retrieved from https://forum.huawei.com/enterprise/en/pci-confusions-vs-pci-collisions/thread/470163-10030.

[4] Swaminathan, S. (2019). RAN-Simulator Impacts, 1–4. Retrieved from https://wiki.onap.org/display/DW/RAN-Simulator+Impacts.

[5] Cheung, Benjamin Begwani, Vimal al, E. (2018). 5G Use Cases for R4/Dublin.

[6] Valastro, G. C., Panno, D., & Riolo, S. (2018). A SDN/NFV based C-RAN architecture for 5G mobile networks. https://doi.org/10.1109/MoWNet.2018.8428882.

[7] Cheung, B. B., & Vimal. (2019). 5G Use Cases for R5/El Alto.

[8] Mohsen, N., & Hassan, K. S. (2015). C-RAN Simulator: A tool for evaluating 5G cloud-based networks system-level performance. https://doi.org/10.1109/WiMOB.2015.7347976.

[9] Cheung, B., & Begwani, V. (2019). 5G Use Cases for R4 / Dublin R4 5G Use Case SUMMARY.

[10] Swaminathan, S Saravanan, A Krishna, Moorthy Mehreen, K Ramya, R Phunith, Kumar Ramesh, R Jeff, Hartley Sandeep, Shah Vineeth, Agarwal Devendra, Chauhan Martin, Skorupski Herbert, Eiselt Hanif, Kukkali Ivan, Seskar Mohit, Sheth Aayush, Shah Dilip, Krishna, T. (2019). OOF-PCI: Physical Cell ID (PCI) Optimization using ONAP Optimization Framework (OOF).

[11]Shankaranarayanan, N. (2019). OOF-PCI Use Case - Dublin Release - ONAP based SON for PCI and.

[12] Swaminathan, S. (2018). RAN Simulator (RAN-Sim). Retrieved from https://wiki.onap.org/pages/viewpage.action?pageId=41419528.

[13] Magnus, Buhrgard Stephen, Terrrill Balaji, Ethirajulu, P. (2019). ONAP and the telecom industry's open-source journey Network.

[14] Kavlak, H., & Ilk, H. for Long Term Evolution Networks, 151–156.

[15] Marsch, P., Da Silva, I., Bulakci, O., Tesanovic, M., El Ayoubi, S. E., Rosowski, T., … Boldi, M. (2016). 5G Radio Access Network Architecture: Design Guidelines and Key Considerations.

[16] Eastcom, H., & Corporation, S. T. (2017). Open Network Automation Platform (ONAP) Project Expands Globally.

Conclusions.

The new mobile technology has a great challenge ahead, the increase of user all over the world and every day the increasing high demand of data by users, has push to the developers and operators of mobile technologies, to improve the networks and increment the number of radio base stations operating, this plus the tendencies of the incoming and already in deploy Internet of things, where a big number of devices will be connected and transmitting information all the time to the mobile networks, has push to the develop of the mobile technology 5G take into account all these scenarios, where the improvement of the LTE technology has taken the main role in the evolve of the new mobile technology.

All these challenges have push to developers and operators to deploy more powerful and cheap networks, this is how the networks has been an important part of the evolution, and tools like RAN Simulator will take a main paper to fulfill this propose, due to the possibility of communicate with ONAP, which is one of the biggest and important projects to achieve the integration of equipment multi-vendor.

The RAN Simulator tool has demonstrated after an evaluation, that is suitable to load and analyze from an external source, as a file information from a network configuration. it is capable to modify factors as PCIs and neighbors relations in order to clear issues regarding PCIs, additional to this the tool keeps track on the changes to follow up, in case that is needed to review any change on the network. The Tool has demonstrated that it is easy to use and modify the values to solve issues regarding PCI, due to is based in a graphical interface, it is very intuitive and easy to understand the functions and show graphically the neighbors relations defined for a selected cell, taking into account the position of them, this can be helpful at the moment of taking decision if it is possible modify the neighbors adding or deleting them.

As contribution to a real case scenario, simulating the addition of a new carrier, which main objective can be provide and start the 5G deployment in a crowded area such a public square, using a free software tool as RAN Simulator it is a good example of the tool works, the tool can be a use in real networks for its deploy and expansion, and this exercise can be taken as precursor and first step to improve a largest network or different scenarios.

The RAN Simulator tool, has demonstrated through the simulation and correction of issues of a real case such as an AT&T network, loaded by a created script, the usability of tools like this in the deploy and improvement of networks such as 5G, where PCI assignation issues as collisions and confusion can be solved, and have direct impact in the performance of a network.

The discussed ways of installation, instructions in how to manage, work and correct issues with RAN Simulator tool, can be taken as a manual for students or professionals in the manage and solve PCI issues, for simulated or real scenarios, all of these with the vision and capabilities offered by the RAN Simulator tool

In a future and next steps to work will be the integration of RAN Simulator and ONAP due to the lack of hardware that prevent the installation, this objective couldn’t been fulfilled. For this cause the next steps to follow will be the integration with a bigger system such as ONAP, which has the capability to manage and operate multi-vendor networks, and mixed networks regarding physical and software based, the possibility of get network details and architecture using a netconf server provided by RAN Simulator, brings the possibility of obtain information of an entire network, perform modifications and improvements through RAN Simulator, and once the network is free of issues upload the changes to ONAP to implement the changes in the network, this open the possibility of a wide number of sceneries were the management, operation and correction of issues can be done in a free software ecosystem, were the information of the network can be easily shared.

The usage of the RAN Simulator tool against typical troubleshooting and analysis, where it is needed to send technicians to do call test in each cell, to confirm that the PCIs works for each cell, have a positive impact to the avoid and reduce of use of vehicles needed to reach the sites, that some cases are far away from cities, and not with easy access, this can be translated to a reduction in expulsed gases by vehicles, which have a direct impact to the environment and a direct affection to increase the global warming.

7. Appendix.

7.1. Installation of RAN Simulator.

The installation of RAN Simulator, needs Docker installed, this in order to run it over a virtual machine with Ubuntu 18.04, the following commands need to be run in the terminal of the virtual machine

- Step 1: Update software repositories

  $ sudo apt-get update

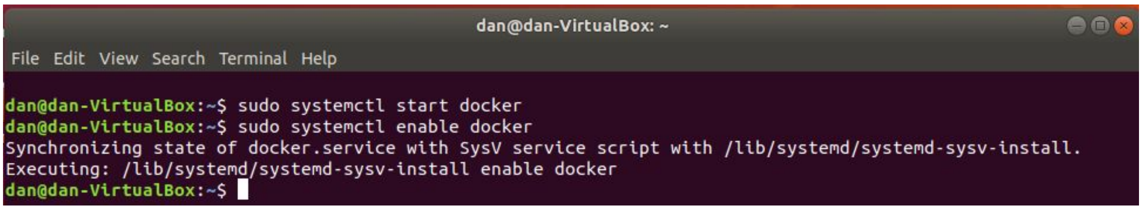
- Step 2: Install Docker

  $ sudo apt install docker.io

- Step 3: Start Docker and set as initiate at startup

  $ sudo systemctl start docker

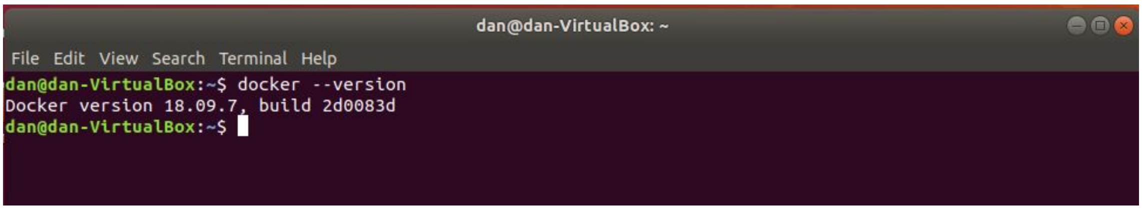
  $ sudo systemctl enable docker



```
dan@dan-VirtualBox:~$ sudo systemctl start docker
dan@dan-VirtualBox:~$ sudo systemctl enable docker
Synchronizing state of docker.service with SysV service script with /lib/systemd/systemd-sysv-install.
Executing: /lib/systemd/systemd-sysv-install enable docker
dan@dan-VirtualBox:~$
```

- Step 4: Verify the installation of Docker

  $ docker --version

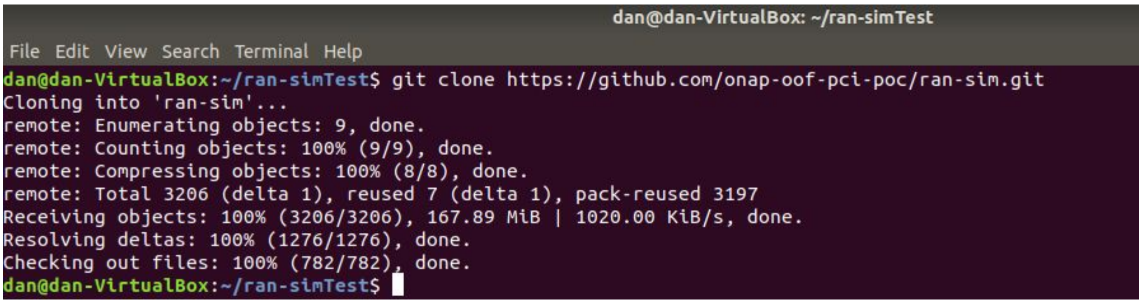


```
dan@dan-VirtualBox:~$ docker --version
Docker version 18.09.7, build 2d0083d
dan@dan-VirtualBox:~$
```

Step 5: Download from Github the repositories of RAN Simulator.

$ git clone https://github.com/onap-oof-pci-poc/ran-sim.git

Once the download is completed we will see a screen as the one below confirming that all the files were successfully downloaded

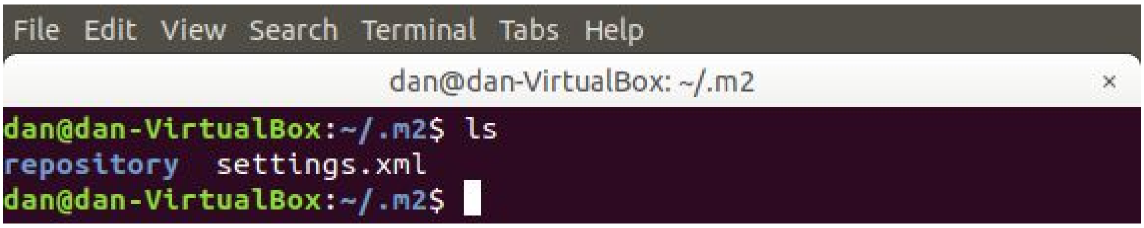

dan@dan-VirtualBox: ~/ran-simTest
File Edit View Search Terminal Help

```
dan@dan-VirtualBox:~/ran-simTest$ git clone https://github.com/onap-oof-pci-poc/ran-sim.git
Cloning into 'ran-sim'...
remote: Enumerating objects: 9, done.
remote: Counting objects: 100% (9/9), done.
remote: Compressing objects: 100% (8/8), done.
remote: Total 3206 (delta 1), reused 7 (delta 1), pack-reused 3197
Receiving objects: 100% (3206/3206), 167.89 MiB | 1020.00 KiB/s, done.
Resolving deltas: 100% (1276/1276), done.
Checking out files: 100% (782/782), done.
dan@dan-VirtualBox:~/ran-simTest$
```

Step 6: It is needed to navigate to the folder where all the files has been downloaded, to the RAN Simulator folder

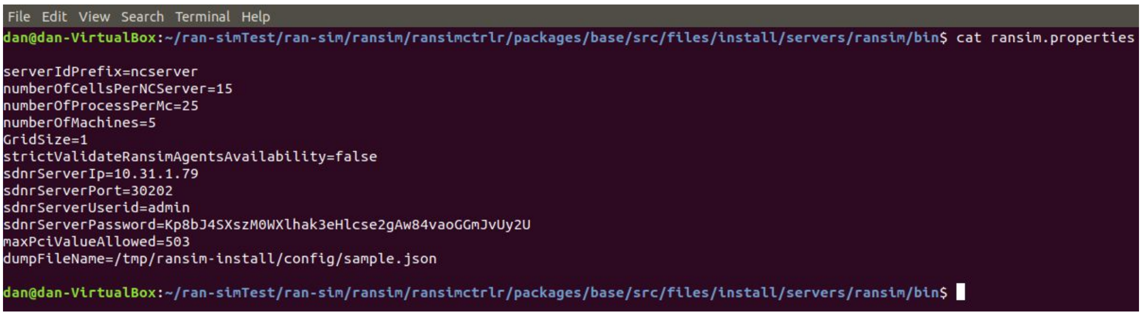
$ cd ran-sim/

Step 7: Copy the file m2_settings.xml contained in /"YOUR FOLDER" /ransim$ to ~/.m2/ folder, and rename the file for settings.xml. if the ~/.m2/settings.xml already exist, merge the content of the file m2_settings.xml to the settings.xml file.


File Edit View Search Terminal Tabs Help
dan@dan-VirtualBox: ~/.m2
×

```
dan@dan-VirtualBox:~/.m2$ ls
repository  settings.xml
dan@dan-VirtualBox:~/.m2$
```

In the directory:
/ransim/ransimctrlr/packages/base/src/files/install/servers/ransim/bin
you can find a file named "ransim.properties" where you can find and modify user capabilities and configuration, for this case we will remain the default configuration.

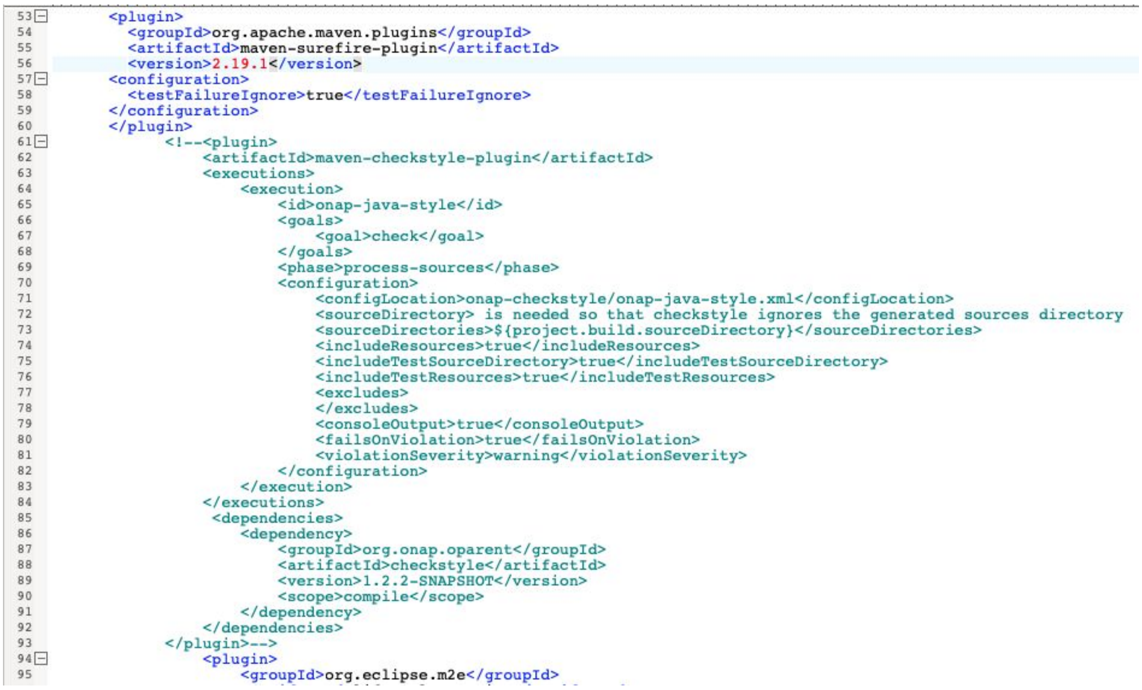


```
dan@dan-VirtualBox:~/ran-simTest/ran-sim/ransim/ransimctrlr/packages/base/src/files/install/servers/ransim/bin$ cat ransim.properties

serverIdPrefix=ncserver
numberOfCellsPerNCServer=15
numberOfProcessPerMc=25
numberOfMachines=5
GridSize=1
strictValidateRansimAgentsAvailability=false
sdnrServerIp=10.31.1.79
sdnrServerPort=30202
sdnrServerUserid=admin
sdnrServerPassword=Kp8bJ4SXszM0WXlhak3eHlcse2gAw84vaoGGmJvUy2U
maxPciValueAllowed=503
dumpFileName=/tmp/ransim-install/config/sample.json

dan@dan-VirtualBox:~/ran-simTest/ran-sim/ransim/ransimctrlr/packages/base/src/files/install/servers/ransim/bin$
```

Step 8: Navigate to the folder /ran-simTest/ran-sim/ransim/ransimctrlr/RANSIM-CTRLR, where you can find a file named “pom.xml” the next modifications need to be done on the file:

Due to some modules are not updated it is needed to comment or delete the part of the script were the file will do a check style on the files.

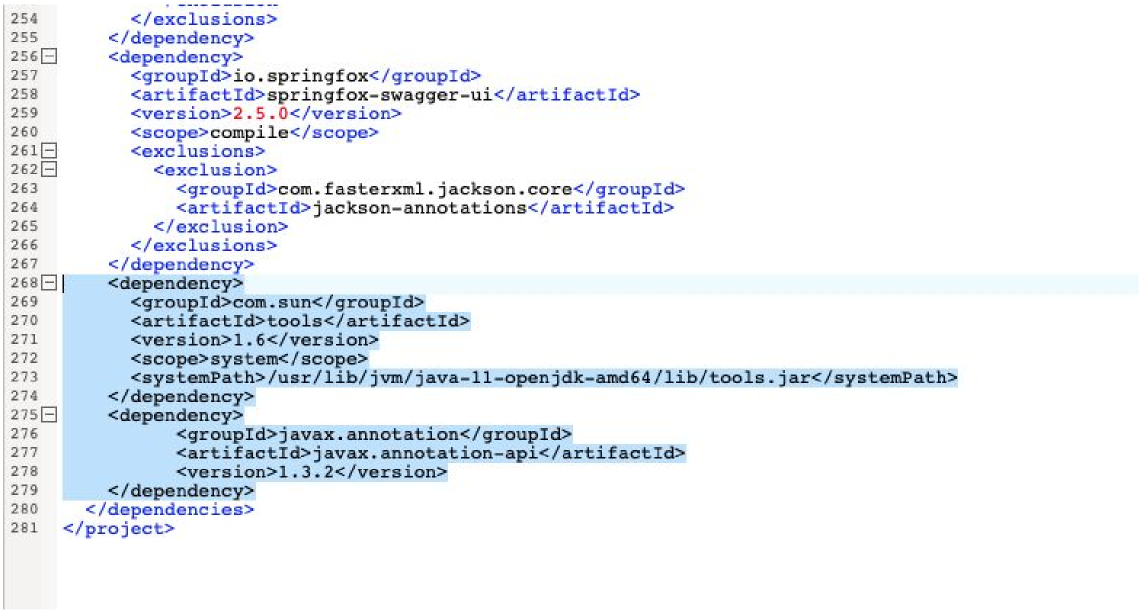
This part of the script can be found from the line 61 to line 93 the plugin related to “chekstyle”



```
53        <plugin>
54          <groupId>org.apache.maven.plugins</groupId>
55          <artifactId>maven-surefire-plugin</artifactId>
56          <version>2.19.1</version>
57        <configuration>
58          <testFailureIgnore>true</testFailureIgnore>
59        </configuration>
60        </plugin>
61              <!--<plugin>
62                  <artifactId>maven-checkstyle-plugin</artifactId>
63                  <executions>
64                      <execution>
65                          <id>onap-java-style</id>
66                          <goals>
67                              <goal>check</goal>
68                          </goals>
69                          <phase>process-sources</phase>
70                          <configuration>
71                              <configLocation>onap-checkstyle/onap-java-style.xml</configLocation>
72                              <sourceDirectory> is needed so that checkstyle ignores the generated sources directory
73                              <sourceDirectories>${project.build.sourceDirectory}</sourceDirectories>
74                              <includeResources>true</includeResources>
75                              <includeTestSourceDirectory>true</includeTestSourceDirectory>
76                              <includeTestResources>true</includeTestResources>
77                              <excludes>
78                              </excludes>
79                              <consoleOutput>true</consoleOutput>
80                              <failsOnViolation>true</failsOnViolation>
81                              <violationSeverity>warning</violationSeverity>
82                          </configuration>
83                      </execution>
84                  </executions>
85                   <dependencies>
86                      <dependency>
87                          <groupId>org.onap.oparent</groupId>
88                          <artifactId>checkstyle</artifactId>
89                          <version>1.2.2-SNAPSHOT</version>
90                          <scope>compile</scope>
91                      </dependency>
92                  </dependencies>
93              </plugin>-->
94                  <plugin>
95                      <groupId>org.eclipse.m2e</groupId>
```

Then is needed to add the next two dependencies on the script, this can be added on the “dependencies” Apart at the bottom of the script.

```
		<dependency>
			<groupId>com.sun</groupId>
			<artifactId>tools</artifactId>
			<version>1.6</version>
			<scope>system</scope>

	<systemPath>/usr/lib/jvm/java-11-openjdk-amd64/lib/tools.jar</systemPath>
		</dependency>
		<dependency>
			<groupId>javax.annotation</groupId>
			<artifactId>javax.annotation-api</artifactId>
			<version>1.3.2</version>
		</dependency>
```

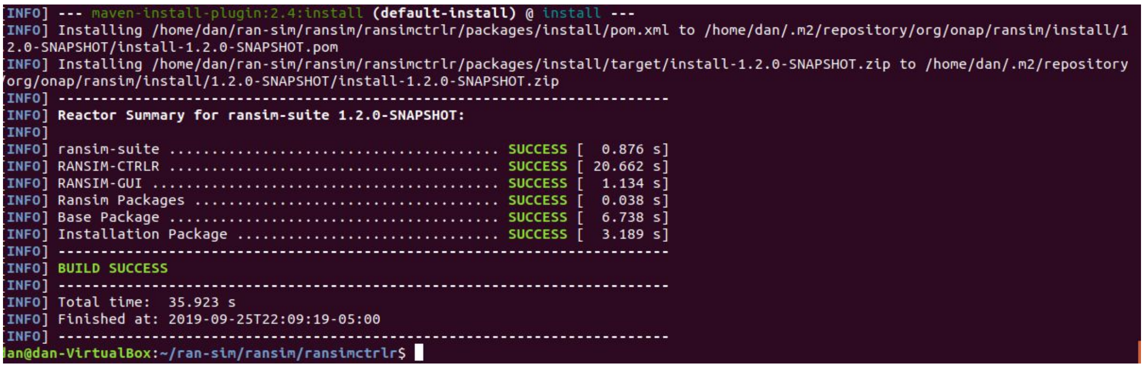


```
      </exclusions>
    </dependency>
    <dependency>
      <groupId>io.springfox</groupId>
      <artifactId>springfox-swagger-ui</artifactId>
      <version>2.5.0</version>
      <scope>compile</scope>
      <exclusions>
        <exclusion>
          <groupId>com.fasterxml.jackson.core</groupId>
          <artifactId>jackson-annotations</artifactId>
        </exclusion>
      </exclusions>
    </dependency>
    <dependency>
      <groupId>com.sun</groupId>
      <artifactId>tools</artifactId>
      <version>1.6</version>
      <scope>system</scope>
      <systemPath>/usr/lib/jvm/java-11-openjdk-amd64/lib/tools.jar</systemPath>
    </dependency>
    <dependency>
          <groupId>javax.annotation</groupId>
          <artifactId>javax.annotation-api</artifactId>
          <version>1.3.2</version>
    </dependency>
  </dependencies>
</project>
```

Step 9: Navigate to the folder /ran-sim/ransim/ransimctrlr and introduce the below command to install modules of the tool

$ mvn clean install

If everything were installed correctly you will received the below messages confirming that the service are ready to start



```
[INFO] --- maven-install-plugin:2.4:install (default-install) @ install ---
[INFO] Installing /home/dan/ran-sim/ransim/ransimctrlr/packages/install/pom.xml to /home/dan/.m2/repository/org/onap/ransim/install/1
2.0-SNAPSHOT/install-1.2.0-SNAPSHOT.pom
[INFO] Installing /home/dan/ran-sim/ransim/ransimctrlr/packages/install/target/install-1.2.0-SNAPSHOT.zip to /home/dan/.m2/repository
/org/onap/ransim/install/1.2.0-SNAPSHOT/install-1.2.0-SNAPSHOT.zip
[INFO] ------------------------------------------------------------------------
[INFO] Reactor Summary for ransim-suite 1.2.0-SNAPSHOT:
[INFO]
[INFO] ransim-suite ....................................... SUCCESS [  0.876 s]
[INFO] RANSIM-CTRLR ....................................... SUCCESS [ 20.662 s]
[INFO] RANSIM-GUI ......................................... SUCCESS [  1.134 s]
[INFO] Ransim Packages .................................... SUCCESS [  0.038 s]
[INFO] Base Package ....................................... SUCCESS [  6.738 s]
[INFO] Installation Package ............................... SUCCESS [  3.189 s]
[INFO] ------------------------------------------------------------------------
[INFO] BUILD SUCCESS
[INFO] ------------------------------------------------------------------------
[INFO] Total time:  35.923 s
[INFO] Finished at: 2019-09-25T22:09:19-05:00
[INFO] ------------------------------------------------------------------------
dan@dan-VirtualBox:~/ran-sim/ransim/ransimctrlr$
```

Step 10: Move to the folder /ransim/docker/ and type the below commands on the terminal.

$ mvn prepare-package

$ sudo docker build -t onap/ransim-demo ransim-docker

Step 11: Edit the file docker-compose.yml located in /ransim/docker/

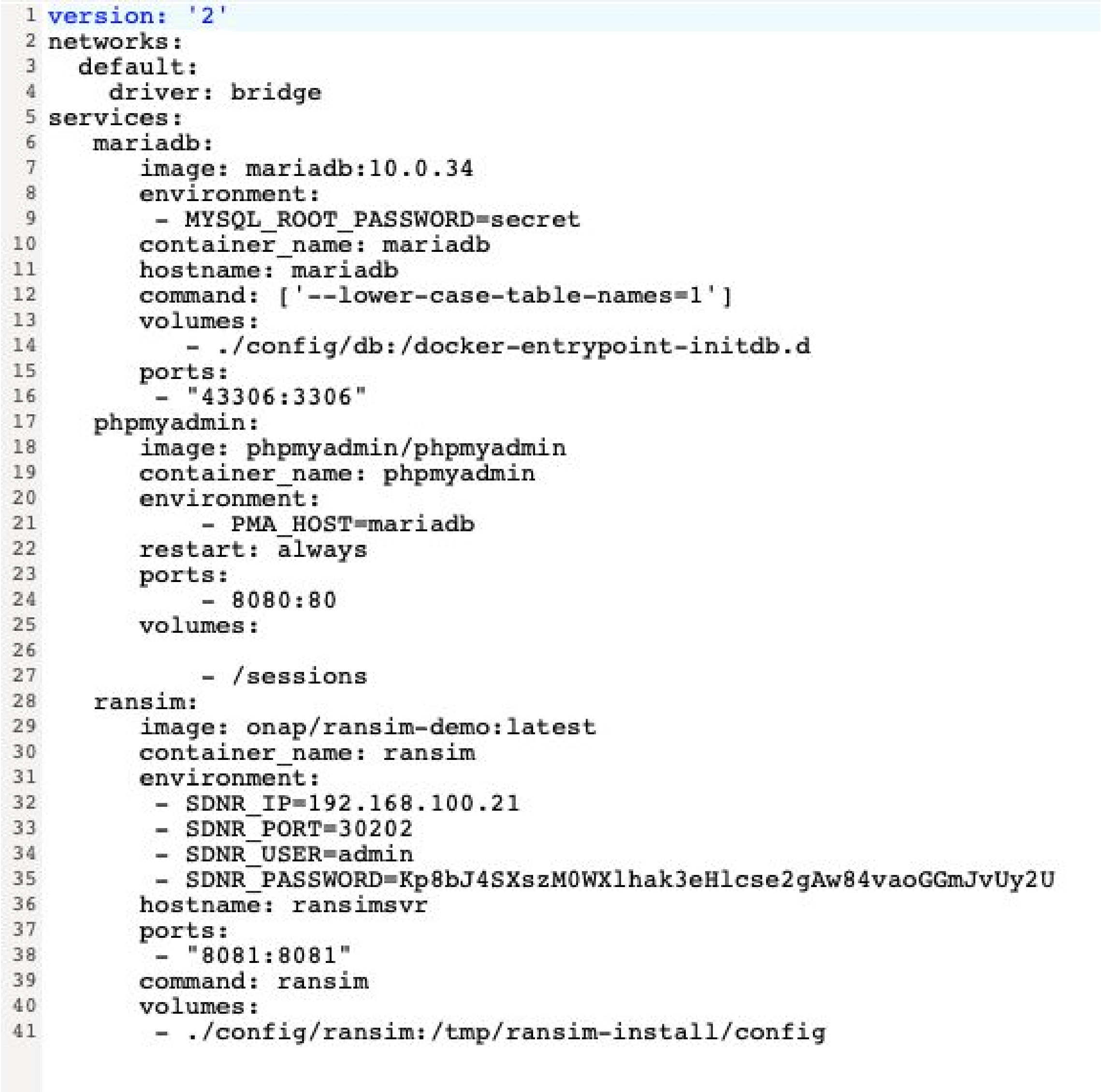
Due to for this exercise we will work locally is needed to comment or delete the two lines of Network configuration:

```
driver_opts:
        com.docker.network.driver.mtu: ${MTU}
```

To have management to the Database that will be created by the system is needed add the below lines to the file.

```
  phpmyadmin:
    image: phpmyadmin/phpmyadmin
    container_name: phpmyadmin
    environment:
      - PMA_HOST=mariadb
    restart: always
    ports:
      - 8080:80
    volumes:

      - /sessions
```

The final file docker-compose.yml must be like the shown below:

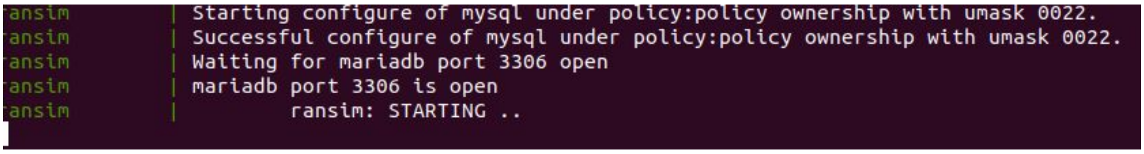


```
version: '2'
networks:
  default:
    driver: bridge
services:
   mariadb:
      image: mariadb:10.0.34
      environment:
       - MYSQL_ROOT_PASSWORD=secret
      container_name: mariadb
      hostname: mariadb
      command: ['--lower-case-table-names=1']
      volumes:
         - ./config/db:/docker-entrypoint-initdb.d
      ports:
       - "43306:3306"
   phpmyadmin:
      image: phpmyadmin/phpmyadmin
      container_name: phpmyadmin
      environment:
          - PMA_HOST=mariadb
      restart: always
      ports:
          - 8080:80
      volumes:

          - /sessions
   ransim:
      image: onap/ransim-demo:latest
      container_name: ransim
      environment:
       - SDNR_IP=192.168.100.21
       - SDNR_PORT=30202
       - SDNR_USER=admin
       - SDNR_PASSWORD=Kp8bJ4SXszM0WXlhak3eHlcse2gAw84vaoGGmJvUy2U
      hostname: ransimsvr
      ports:
       - "8081:8081"
      command: ransim
      volumes:
       - ./config/ransim:/tmp/ransim-install/config
```

Step 11: To bring up all the services type the below command in the terminal:

$ sudo docker-compose up

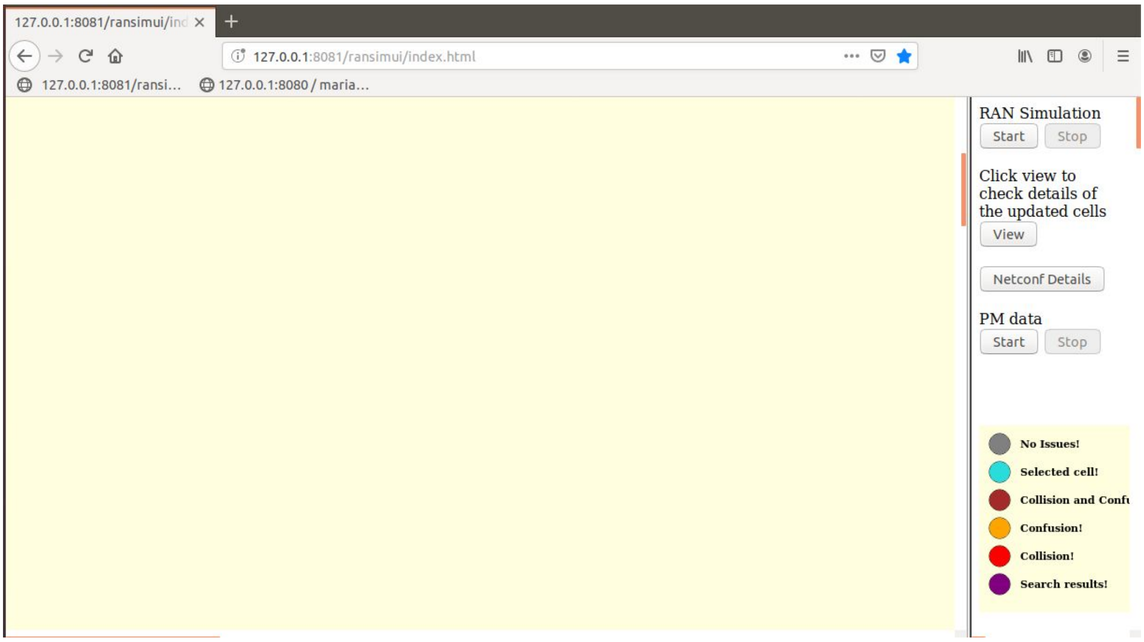
You will see a image as below confirming that RAN Simulator is ready:



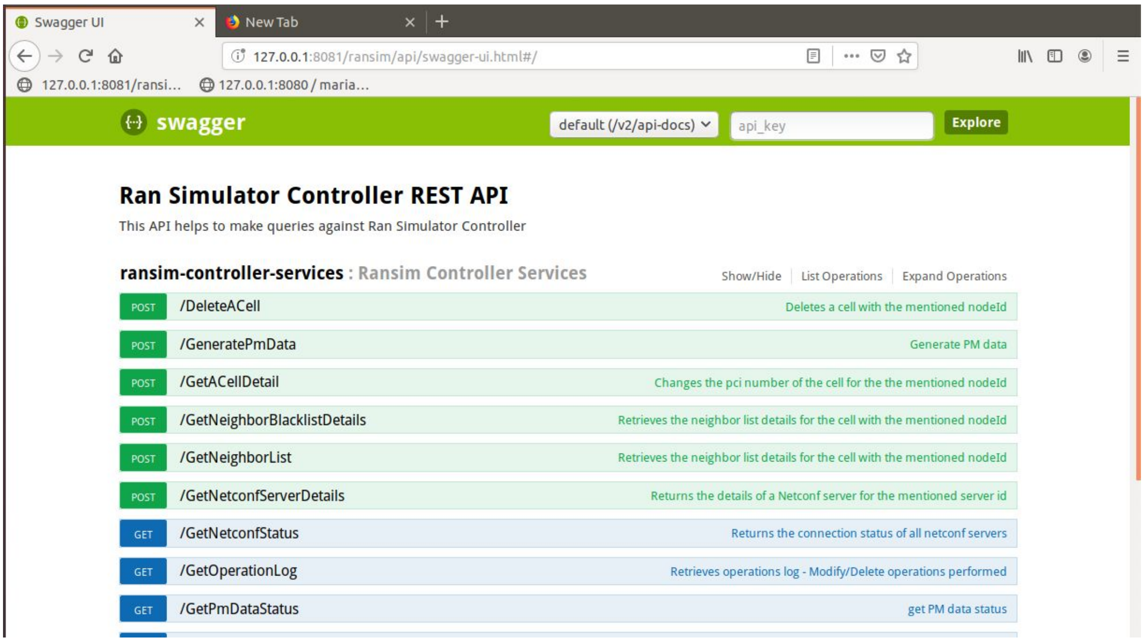
```
ansim         | Starting configure of mysql under policy:policy ownership with umask 0022.
ansim         | Successful configure of mysql under policy:policy ownership with umask 0022.
ansim         | Waiting for mariadb port 3306 open
ansim         | mariadb port 3306 is open
ansim         |        ransim: STARTING ..
```

Step 12: To get access to the tool is needed an browser to get access to it.

Use: http://127.0.0.1:8081/ransimui/index.html To get Access to RAN Simulator



Use http://127.0.0.1:8081/ransim/api/swagger-ui.html#/ to get access to Ran Simulator Controller



Ran Simulator Controller REST API

This API helps to make queries against Ran Simulator Controller

ransim-controller-services : Ransim Controller Services

POST	/DeleteACell	Deletes a cell with the mentioned nodeId
POST	/GeneratePmData	Generate PM data
POST	/GetACellDetail	Changes the pci number of the cell for the the mentioned nodeId
POST	/GetNeighborBlacklistDetails	Retrieves the neighbor list details for the cell with the mentioned nodeId
POST	/GetNeighborList	Retrieves the neighbor list details for the cell with the mentioned nodeId
POST	/GetNetconfServerDetails	Returns the details of a Netconf server for the mentioned server id
GET	/GetNetconfStatus	Returns the connection status of all netconf servers
GET	/GetOperationLog	Retrieves operations log - Modify/Delete operations performed
GET	/GetPmDataStatus	get PM data status

Use http://127.0.0.1:8080/index.php with the credentials Username: “root” Password: “secret” to get access to the management of the database created by RAN Simulator

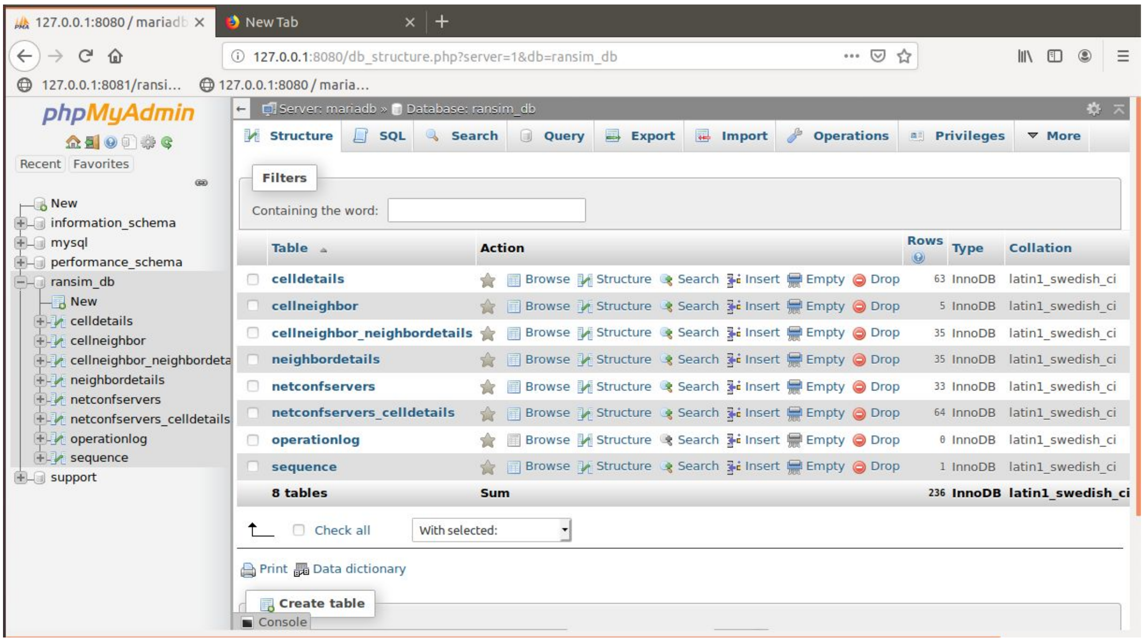


	Table	Action	Rows	Type	Collation
□	celldetails	☆ Browse Structure Search Insert Empty Drop	63	InnoDB	latin1_swedish_ci
□	cellneighbor	☆ Browse Structure Search Insert Empty Drop	5	InnoDB	latin1_swedish_ci
□	cellneighbor_neighbordetails	☆ Browse Structure Search Insert Empty Drop	35	InnoDB	latin1_swedish_ci
□	neighbordetails	☆ Browse Structure Search Insert Empty Drop	35	InnoDB	latin1_swedish_ci
□	netconfservers	☆ Browse Structure Search Insert Empty Drop	33	InnoDB	latin1_swedish_ci
□	netconfservers_celldetails	☆ Browse Structure Search Insert Empty Drop	64	InnoDB	latin1_swedish_ci
□	operationlog	☆ Browse Structure Search Insert Empty Drop	0	InnoDB	latin1_swedish_ci
□	sequence	☆ Browse Structure Search Insert Empty Drop	1	InnoDB	latin1_swedish_ci
	8 tables	Sum	236	InnoDB	latin1_swedish_ci