Improving the Connectivity of Mobile Networks Through the Use of Deep Learning for Planning Neighborhood Relations

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Abstract
This work proposes a Deep Learning approach to help mobile operators plan neighborhood relationships within their network in the form of an application allowing to map sites, sectors and their cells, to calculate the neighbors of different cells based on deep learning algorithms and integrate new sectors or sites on the network. By leveraging complex machine learning techniques, the tool developed can identify patterns, trends and hidden relationships between different base stations in the network. This leads to more effective and efficient planning of neighbor relationships, thereby reducing interference and improving quality of service for subscribers. Additionally, the tool offers increased flexibility and adaptability. It is able to adjust to rapid network changes, such as adding new base stations or changing a network site's settings. This ability to adapt guarantees continuous and optimal planning of neighborhood relations, even in a dynamic and evolving environment.

Keywords: Deep Learning, neighborhood relation planning, radios sites, RAN, Handover

1. Introduction

Telecommunications networks play an increasingly crucial role in our society. To meet customer needs and interests, operators must be able to provide high-quality services at competitive prices. It is in this context that the problem of network planning falls, which aims to optimize the costs linked to the installation and use of the system. Effective planning helps reduce deployment time, capital expenditure and operational costs.

In this ever-changing landscape, artificial intelligence is emerging as a key player, offering innovative solutions for mobile network planning and optimization. Thanks to its big data processing and machine learning capabilities, artificial intelligence and machine learning in particular bring a new dimension to mobile network planning. For the specific case of neighborhood relations planning, there are intelligent tools that use algorithms and geographic data to propose optimal solutions. These tools save time, reduce errors and improve network performance. However, these tools are not always adapted to the specificities of each operator or each country.

In this context, the present work aims to design and produce an intelligent tool for planning neighborhood relations in an optimal manner to ensure homogeneous coverage, high quality of service and operational efficiency in 2G/3G networks. The tool is based on existing network data, technical and regulatory constraints, and quality criteria defined by the operator.

2. Neighborhood relations in mobile networks

2.1. *The Handover*

Handover or intercellular transfer is a fundamental mechanism in cellular mobile communications (GSM, CDMA, UMTS or LTE). Handover refers to all the operations implemented to allow a mobile phone or Smartphone (called mobile station - MS in GSM, or user Equipment in 3G and 4G networks) to change radio cell without interruption of the conversation or data transfer. This mechanism can be supplemented by a roaming service, which occurs in the case where the mobile station leaves a cell managed by one operator for another belonging to another operator, whether or not there is a conversation in progress course (Benariba, 2023).

2.1.1. Objectives of Handover

Overall, Handover has several functions (Fouelefack, 2015):

- Allow movement during a communication;
- Avoid breaking the link due to radio “rescue Handover”;
- Balance traffic between “traffic handover” cells, Maintain acceptable quality if interferers arrive;
- Optimize the use of radio resources by minimizing energy consumption and the overall level of interference “Handover containment”.

2.1.2. Handover measures

The Handover process begins when a mobile node needs to leave its point of attachment to the current network to connect to another network where the quality of service will be better. Typically, the reason may be low signal strength or a value of one or more QoS parameters falling below a certain threshold.

Several parameters make it possible to judge the quality of the radio link, namely:

2.1.2.1.Received power level RxLev

The field level coming from the BTS measured at the mobile level is called the RxLev. It is measured on 64 levels, from 0 to 63 respectively representing powers from -110 to -47 dBm in steps of 1 dB.

There are four types of service: “Indoor” service, “Deep Indoor”, “Soft Indoor”, “Outdoor” service, “Incar” service.

Table 1. Summary of field levels according to services (ARCEP, 2023)

Types of services	Description	Field levelre-who
DeepIndoor	Allows the smooth running of communications inside buildings	-65dBm to -47dBm
Indoor	Allows communications to run smoothly within buildings ments.	-75dBm to -65dBm
Incar	Who takes into account the users found in a car.	-85dBm to-75dBm
Outdoor	Which indicates the conditions necessary for the smooth running of a outdoor communication.	-95 dBm to -85 dBm
BadService		-110dBm to -95dBm

2.1.2.2. RxQual signal quality:

The signal quality is evaluated via the RxQual parameter. It is obtained by quantifying the bit error rate BER, Bit Error Ratio, on 8 levels (3 bits) following the correspondence defined in the table below:

Table 2 – Summary table of quality levels (ARCEP, 2023)

Good quality	0-4
Averagequality	5-6
Bad quality	7

• ***Received Signal Strength Indicator (RSSI)****:*

Signal power on the 5 MHz band, so this is the power measured from all base stations.

2.2. Planning neighborhood relations within the 2G/3G network

RAN planning engineers are responsible for planning, installation and maintenance of the network. The aim of their actions is not only to be able to ensure good network coverage in urban and rural areas, but also and above all to guarantee good quality of service. This requires a good configuration of neighborhood relations. To help them in this mission, the operator made NOKIA's EdenNET tool available to them. This is a C-SON (Centralized-Self Organization Network) technology.

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The objective of SON during network optimization is to maintain the desired level of performance over the life of the network as new equipment is deployed. Automation particularly concerns the automatic adjustment of network parameters based on radio measurements. SON is therefore defined as a process based on measurements made between terminals (UE) and base stations to self-adjust radio parameters. The parameters to be adjusted are the transmission power, information from neighboring cells for Handover and other parameters managed by the lower layers (RRC/MAC/PHY). The SON module responsible for the automatic configuration of neighborhoods is called ANR (Domoina, 2023).

2.2.1. Constraint

Neighborhood planning must take into account the following limitations (NOLIA, 2015):The maximum number of intra-frequency neighbors is limited to 32 (same EARFCN);

- The maximum number of neighbors in inter-frequency is limited to 64 (different EARFCN);
- The maximum number of neighbors in inter-RAT is limited to 64 (3G => 2G);
- The maximum number of neighbors in inter-RAT is limited to 32 (2G => 3G);
- Geographically adjacent cells must be declared as neighboring cells;
- Neighborhood relationships are bidirectional except in exceptional cases where we may see a unidirectional relationship.

2.2.2. 2G/3G Neighborhood strategy

The 2G/3G neighborhood strategy is summarized in the following table and includes aspects such as (Nokia, 2015):

- Co-sector neighborhood relationships have priority over co-site neighborhood relationships which in turn have priority over inter-site neighborhood relationships;
- Among the inter-site neighborhood relations, we will favor the neighborhood relations of the 1st ring then that of the 2nd ring and so on...
- When creating inter-site neighborhood relationships on a crown, inter-rat neighborhood relationships are the lowest priority.

Table 3.Importances of neighborhood relations(Nangmo, 2015)

HANDOVER RELATION	DESCRIPTION	PRIORITY DEGREE
CO-SECTOR	These are neighbourhood relationships between cells belonging to the same sector.	1: the mosthighestpriority
CO-SITE	These are cells belonging to the same site	2: the second most highest priority
INTER-SITE(1erecou-ronne)	A cell and all its cells in direct visibility are in a Handover relationship called the first ring relationship.	3:thirddegreepriority
INTER-SITE (2e crown	They are in direct visibility with the cells of the 1st ring of the source cell	4:fourthdegreepriority
INTER-SITE (3e crown	They are in direct visibility with the cells of the 2nd ring of the source cell	5:fifthdegreepriority
...	....	...
INTER-SITE (nième crown)	They are in direct visibility with the cells of the (N-1)th crown of the source cell	N+2:prioritydegree N+2

2.2.3. Classification of 2G/3G neighborhoods

Once the configuration of the neighborhood relationships has been completed, these relationships must be classified according to the 03 types of neighborhood relationship planning in mobile networks (NOKIA, 2015):

- Co-sector neighborhood relationships have priority over Co-site neighborhood relationships which in turn have priority over inter-site neighborhood relationships;
- Among the inter-site neighborhood relations, we will favor the neighborhood relations of the 1st ring then that of the 2nd ring and so on...
- When creating inter-site neighborhood relationships on a crown, inter-rat neighborhood relationships are the lowest priority.

Table 4. Importance of neighborhood relations (Nangmo, 2015)

HANDOVER RELATION	DESCRIPTION	PRIORITY DEGREE
CO-SECTOR	These are neighborhood relationships between cells belonging to the same sector.	1: highest priority
CO-SITE	These are cells belonging to the same site	2: second highest priority
INTER-SITE(1st crown)	A cell and all its cells in direct visibility are in a Handover relationship called the first ring relationship.	3: third degree priority
INTER-SITE (2^{ND} Crown)	They are in direct visibility with the cells of the 1st ring of the source cell	4: priority of degree 4
INTER-SITE (3^{rd}Crown)	They are in direct visibility with the cells of the 2nd ring of the source cell	5: priority of degree 5
...	....	...
INTER-SITE (Nth Crown)	They are in direct visibility with the cells of the (N-1)th crown of the source cell	N+2: priority of degree N+2

2.2.4. Classification of 2G/3G neighborhood

Once the configuration of the neighborhood relationships has been completed, these relationships must be classified according to the 03 types of neighborhood relationship planning in mobile networks [5]:

2.2.4.1. HandoverINTER-RAT

This involves the transfer of the mobile device from one network to another network with a different communication technology. We will therefore have:

- **ADJG** type neighborhoods: here, the intercellular transfer takes place from a 3G cell to a 2G cell;
- **ADJW** type neighborhoods: here, the intercellular transfer takes place from a 2G cell to a 3G cell.

2.2.4.2. HandoverINTRA-FREQUENCE

Here, the mobile device is transferred to another cell which uses the same frequency as the original cell. We will have:

- **ADCE** type neighborhoods: here, the intercellular transfer takes place from a 2G cell to another 2G cell of the same frequency;
- **ADJS** type neighborhoods: here, the intercellular transfer takes place from a 3G cell to a 3G cell of the same frequency.

2.2.4.3. Handover INTER-FREQUENCE

In this scenario, the mobile is transferred to another cell which uses a frequency different from the initial cell. We will have:

- **ADJI** type neighborhoods: here, the intercellular transfer takes place from a 3G cell to another 3G cell of a different frequency;

2.2.5. Generation ofOT's file

Once this classification is completed, we can easily generate the work order file specific to each category of neighborhoods which will be implemented by the Nokia teams at the BSS level, so that it actually works on the network. We have a command file like the one in Figure 1:

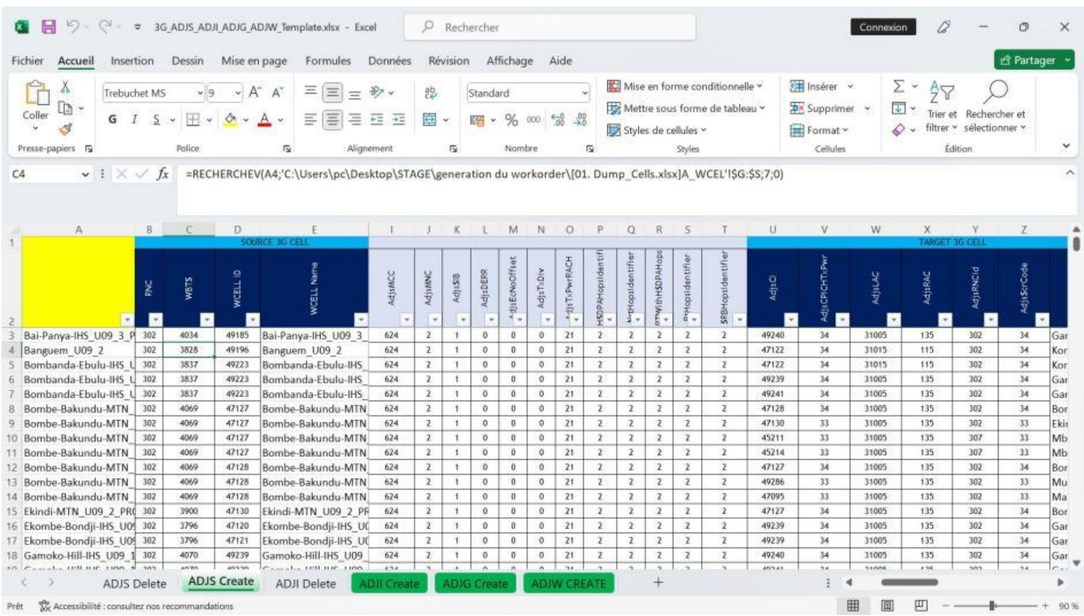

Figure1.Example of OT file on Excel

2.4. Planning tools used and work on the subject

2.4.1. The tools

2.4.1.1. Plan_checkerde MAPINFO

The Map-Info Plan_Checker plugin is a mapping tool that provides an overview of the cellular network. It focuses on the operations of creating and deleting neighborhood relationships, as well as the visualization of point relationships as shown in Figure 2

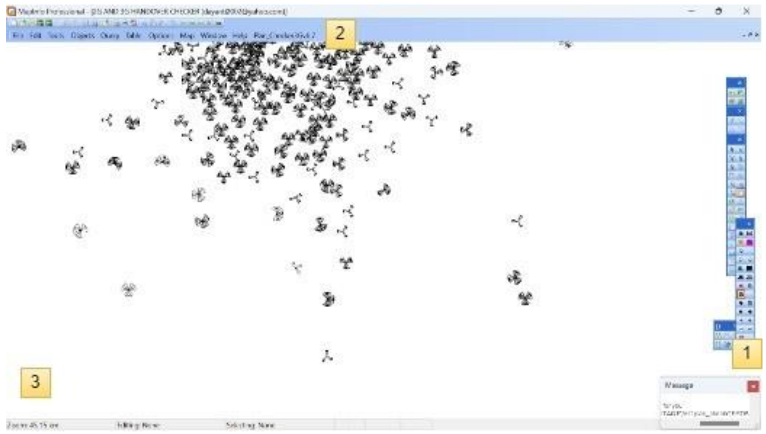

Figure2.– Plan interface checker

The interface of this tool presents:

1: a toolbar which will allow you to carry out operations on the neighborhoods; the name of the plugin used on map info, here it is plan_checker.

2: The map area where all sites are displayed.

2.4.1.2. UNETofHUAWEI

U-Net is a professional tool that fully supports wireless network planning. For example, U-Net can be used to plan the network using both GSM technology and UMTS technology or LTE technology. Throughout the network lifecycle, U-Net helps operators complete initial network design, network simulation, coverage prediction and network optimization.

2.4.1.3. Tool Quick Neigborsde Ericsson

Tool Quick Neigbors is an advanced tool for 2G, 2.5G and 3G design and planning. Designed and developed by Ericsson, it provides planning capabilities to save time during mass deployment of network radio sites. The algorithms implemented in this tool take into account relationship categories.

2.4.2. Some work on neighbourhood relations

There is some recent work in the literature carried out in the area of neighbourhood relations planning.

a) In [6], the author highlights the problems that can arise following a poor configuration of neighborhood relations. His work focuses on “Monitoring and fine optimization of Handover relationships in the Orange Cameroon network”. As functionalities developed according to Figure 3, we have:

a) As functionalities developed according to Figure 3, we have:

b)The creation and suppression of neighbourhood relations.

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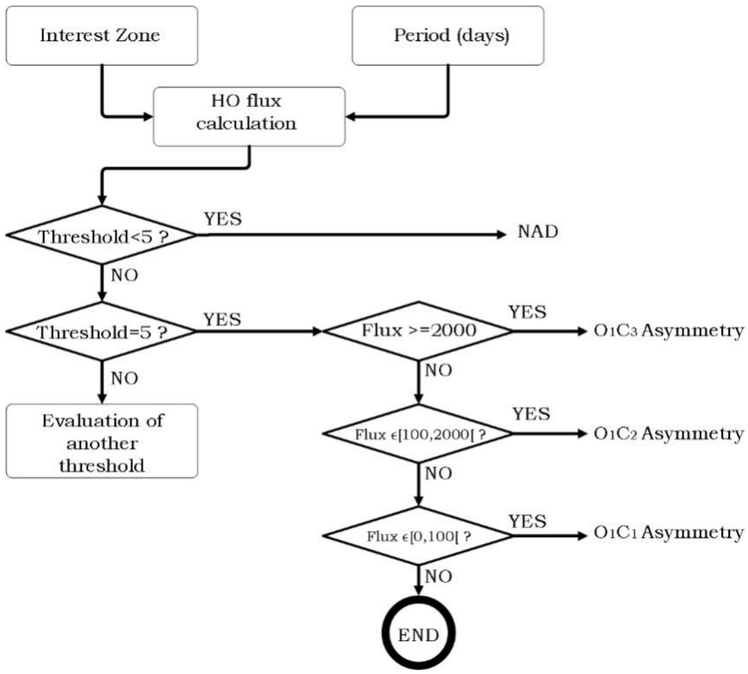

Figure 3. Flowchart of asymmetry detection (Nangmo, 2013)

Handover asymmetries can vary depending on different factors such as environment (urban or rural) and days of the week. In order to detect these asymmetries in a more coherent and relevant way, a distinction is made between "small HO flows" and "large HO flows". This distinction is categorized in to three levels:

- Category 1 (C1) for small flows;
- Category 2 (C2) for flow means;
- Category 3 (C3) for large flows.

Additionally, these asymmetries are also classified in an order, determined by a specific threshold:

- an asymmetry threshold of 5 for first-order asymmetry (O1);
- a threshold of 10 for second-order asymmetry (O2);
- a threshold of 100 for a third order asymmetry (O3).

By combining the order and asymmetry category, different asymmetry classes can be output, such as O1C1, O2C3, O3C2, etc.

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Ideally, asymmetries are considered anomalies, because it is preferable that the Handover exchanges between two cells are balanced in both directions.

b) In (Fouelefack, 2015) the author worked on “the design and creation of a tool for configuring neighborhood relations and integration of mobile radio sites: case of the CAMTEL CDMA network. » Developed using the VB.NET language, this GIS application offers the following functionalities:

•Map the network’s radio sites;

- Integrate a digital terrain model (DTM) to obtain site elevations;
- Add a new site to the network;
- Base on the parameters (azimuth and elevation), to determine the neighbors of each sector of the network;
- Generate MML commands for configuring these relationships at the BSC level;
- Connect to the BSC and execute the generated configuration commands.

c) Limits of existing solutions

The work of (Domoina, 2023) has the following limitations:
• He does not assist the Engineer with the integration of the new site;
• Moreover, we are not creating neighborhood relationships strictly speaking, but rather optimizing the existing configuration;
• It does not take into account 3G standards;
• Does not give a global vision of the network (absence of mapping);
Does not generate work order file

However, there is a strong dependence on planning tools by mobile operators (UNET, SON, etc.). The work of (Fouelefack, 2015) does not take into account the GSM standard; it is specific to the CAMTEL context. And therefore does not take into account certain concepts validated by other mobile operators. In addition, the use of the latter seems a little complex.

3. Method and Tools

3.1. *Radio planning and artificial intelligence*

Machine learning algorithms, and in particular deep learning algorithms, are generally particularly effective for representing and analyzing complex situations when a significant amount of information is available. Telecommunications networks are complex objects comprising numerous components with numerous parameters on which it is possible to act, which makes their modeling with a view to their optimization complex. Telecommunications networks also generate a very large quantity of data on their operation (notably quality of service indicators, availability rates, telemetry data, etc.) allowing their operators to have a precise image of their performance. This complexity and abundance of data have naturally led operators and equipment manufacturers to be interested in machine learning techniques to optimize the operation of networks.

3.2.3 Deeplearning

Deep Learning was derived from the neural networks of the human brain which is truly complex. By carefully studying the brain, scientists and engineers have developed an architecture that could fit into our binary digital world. One of these typical architectures is shown in the diagram in Figure 4:

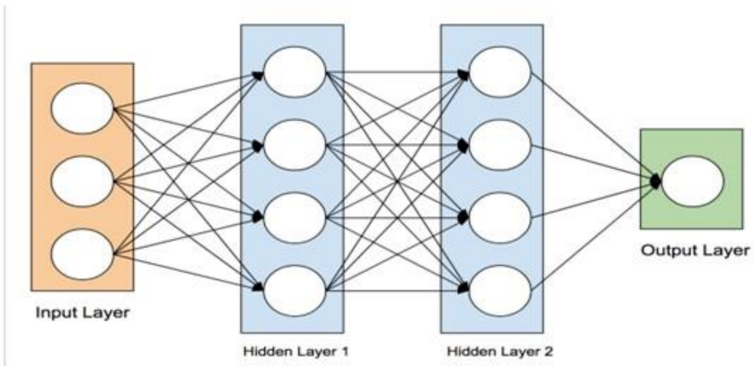

Figure4–Deep learning network(TONYE, 2020):

A neural network is generally made up of a succession of layers. This model includes (Tonye, 2020):

- Three elementary operations: multiplication, summation and activation;

- Input data which is consumed by the neurons of the first hidden layer. Each layer can have one or more neurons. The connection between two neurons of successive layers would have an associated weight which defines the influence of the input on the output of the next neuron and possibly on the overall final output. On each artificial neuron, each input value is multiplied by the corresponding weight. Then, the result obtained will be added to what is called the bias to apply an activation function to it at the end;

$$y = f(\sum_{i=1}(\Omega_i * x_i + b) \quad (1)$$

where:

-f: activation function

- xi: an input;

- i: the weight associated with an entry

- b: the bias

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The idea is to find the optimal weights and biases to minimize the cost function in a deep neural network. However, the challenge of Deep Learning lies in the difficulty of finding these optimal parameters for deep neural networks of large size and complexity, due to the large number of parameters to adjust and the non-linearity of the activation functions.

3.2.4.3 Model evaluation

We have several ways to evaluate a learning algorithm, among these, the most widespread are (TONYE, 2020):

-Cross entropy: is an error function, that is to say the distance between the vector of known elements and the vector of probabilities calculated by the neuron; The latter is represented by the following formula:

$$-\sum Y_i' * log(Y_i) \qquad (2)$$

Where:
- Yi': the elements of the supervision vector;
- Yi: the elements of the probability vector;

3.3 System conception

The approach adopted to create our solution is presented in Figure 5:

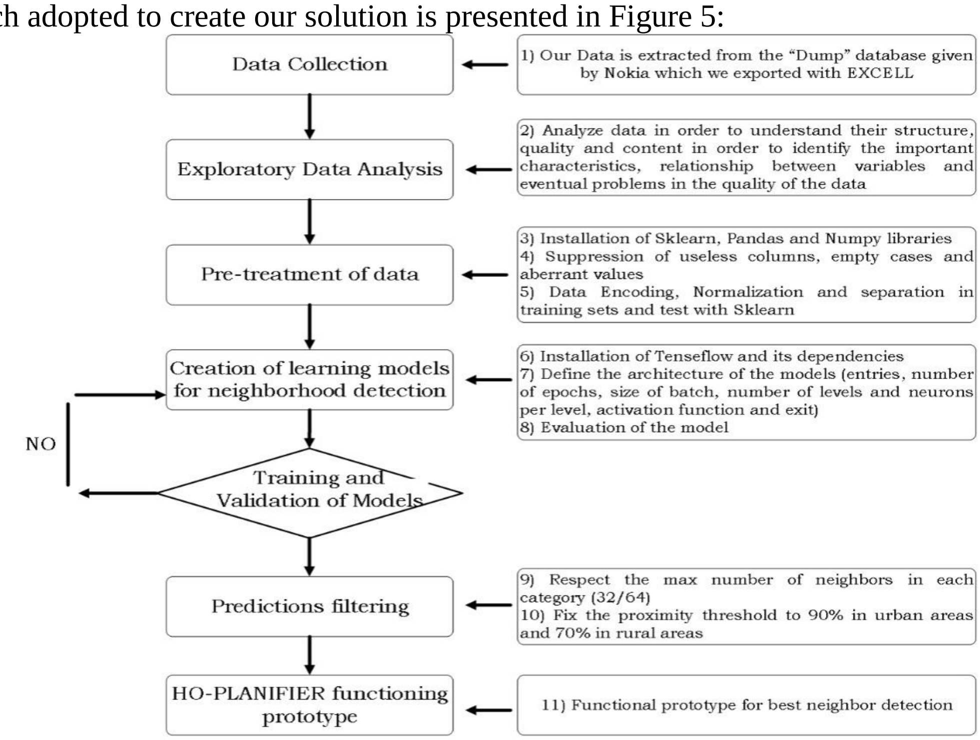

Figure 5. Diagram of methodological steps

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We will then detail the different stages covered in our approach.

3.3.1 Data collection and analysis
The data used by our different machine learning models comes from Dump Cells, an Access database for storing cell parameters as well as neighborhood relationships present in the OCM network [Gonta, 2023). This is a set of files containing the different cell parameters depending on the technology. Information can be classified into 03 categories:

- Identification parameters such as: the name of the **BTS (BTSNAME)**, the name of the site **(SITENAME)**, the identifier of the cell **(SiteCellId)**;
- Geographic parameters such as: longitude **(X)**, latitude **(Y)**, azimuth
(AZM1), the identifier of the LAC to which the cell belongs **(SourceLAC)**;

- Technological parameters which are grouped into two categories:

- For a 2G cell, we will have: **BSCid, BCF, BTSid, BCCH,NCC,BCC...**

- For a 3G cell, we will have: **rncId, sac, RAC, scramblingCode, UARFCN, WBT-Sid, LcrId...**

3.3.2 Data preprocessing
Generally speaking, in data science, data never arrives in a directly usable form. Deep learning is no exception. In reality, most of the work consists of working directly on the data: shape, composition, etc. When we extracted our data from DUMP, we noticed that there were both quantitative variables like longitude and qualitative variables like BTSid, rncId... Given that in AI, we manipulate values numeric and not character strings. This implied firstly to filter the data to eliminate qualitative variables non-usable or useless (which do not provide information on a neighborhood relationship). And secondly an encoding (more precisely a digitization) to convert the strings into digital values. The entire data preprocessing phase was carried out in Python thanks to its particularly practical libraries such as numpy and pandas.

3.3.3 Data separation
Separating data into training and testing sets is an important part of evaluating deep learning models. When we split a dataset into a training set and a test set, most of the data is used for training (typically 80%), and a smaller portion of the data is used for testing (20%).). Next, we randomly sample the data to ensure that the test and training sets are similar. By using similar data for training and testing, we can minimize the effects of data discrepancies and better understand the model's characteristics. Once a model has been processed using the training set, we test the model by making predictions against the test set.
The three phases carried out above constitute the data preparation stage as shown in Figure 6.

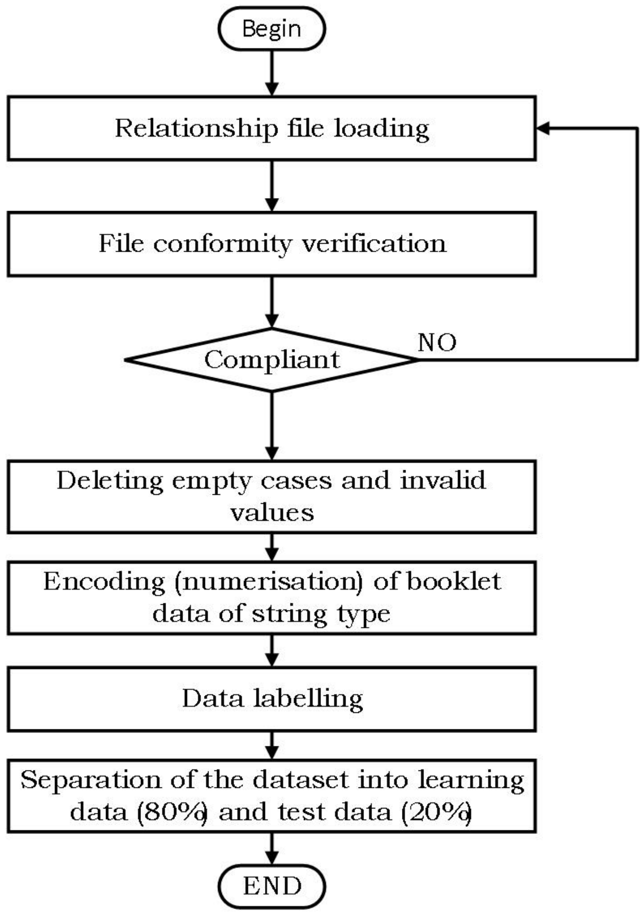

Figure 6. Data preparation algorithm

3.3.4. Model formation

This step corresponds to the most delicate part of machine learning. The model is trained by injecting the data collected and cleaned in the previous steps. In our supervised learning model, they were separated into input variables ("feature set") and output variables ("target set"). The training phase therefore consists of the model improving its capacity, progressively and iteratively. This improvement involves adjusting hyperparameters such as: the number of layers, the number of neurons per layer, the activation function, the batch size and the number of epochs. All while minimizing an error/cost function. We focused on the quality of the data and their representativeness of the situation at hand analyze in order not to introduce bias into the results while maintaining optimal precision. Its algorithm is summarized in Figure 7.

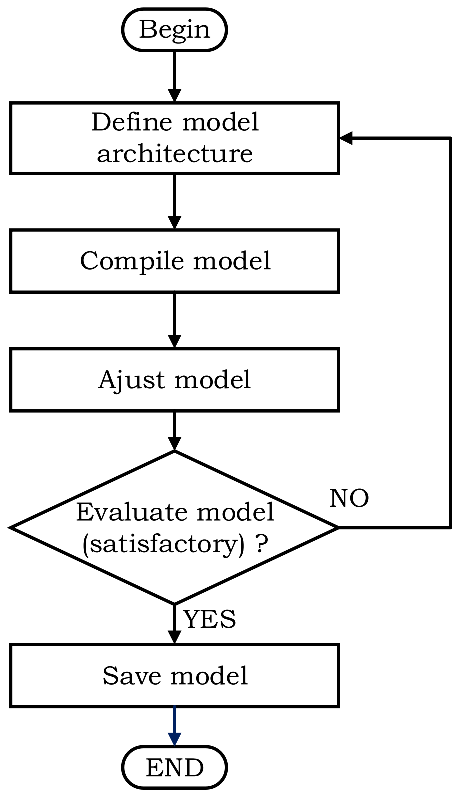

Figure 7. Model training algorithm

3.3.5. Functioning Principe

The user enters data from the cell whose neighborhoods he wants to know. Then, He chooses the neighbor detection algorithm (2G=>2G, 3G=>3G...) which interests him depending on the type of relationship he wants to implement. The model will evaluate the degree of proximity of our source site to all other sites in the network. See figure 8:

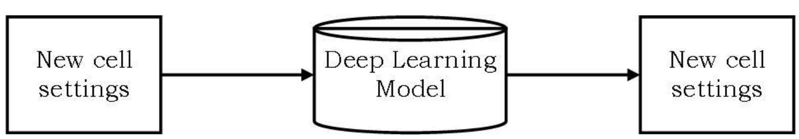

Figure 8. Obtaining predictions

Then, filtering is performed to provide the best possible neighborhoods. The filtering will take into account two elements, namely:

-**zone type**: ruralorurban;

-**Declarations limits**: 32 or 64 model functions. See the algorithm in Figure 9 showing the filtering of results.

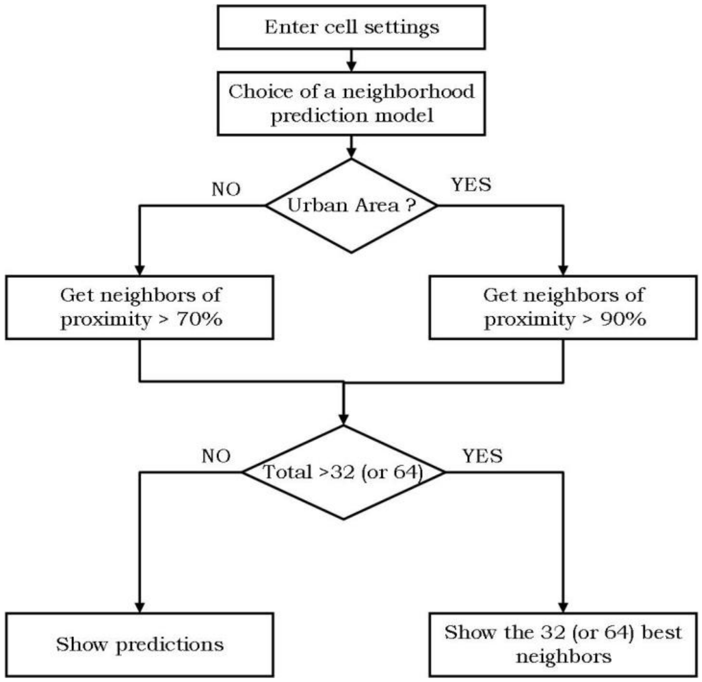

Figure 9. Filtering results

3.4. Modalisation of the system

3.4.1.2 Functional analysis

The main features of our system are:

- Manage network sites: The tool we are developing will provide all the information relating to network cells as well as their neighbourhoods. We can also add network sites or add cells to existing sites.

- **Plan neighbourhoodrelations**: This involves the user using the parameters of a particular cell to determine its neighbouring cells. To do this, we first use the different deep learning algorithms to determine the neighbours following each category of relationships then we list the predicted relationships which we will display if necessary on a map in order to validate or optimize the prediction and finally we generate the work order while refreshing the database.

- Optimize neighbourhoodrelations: Optimization occurs to the extent that the technician is not completely satisfied with the configuration proposed by the AI. He can then either delete or add neighborhood relationships as he wishes and then save his configurations in the database.

- Generate the work order: The culmination of this work is the generation of the work order file which will be implemented by the NOKIA teams. At the end of the configurations, a work order will be automatically generated in EXCEL format.

- **Manage users:** The user logs in, logs out, changes their password, and resets it. In addition to all this, the administrator will be able to add/delete user accounts.

3.4.3. Use case diagram

The diagram is presented in the following figure 10:

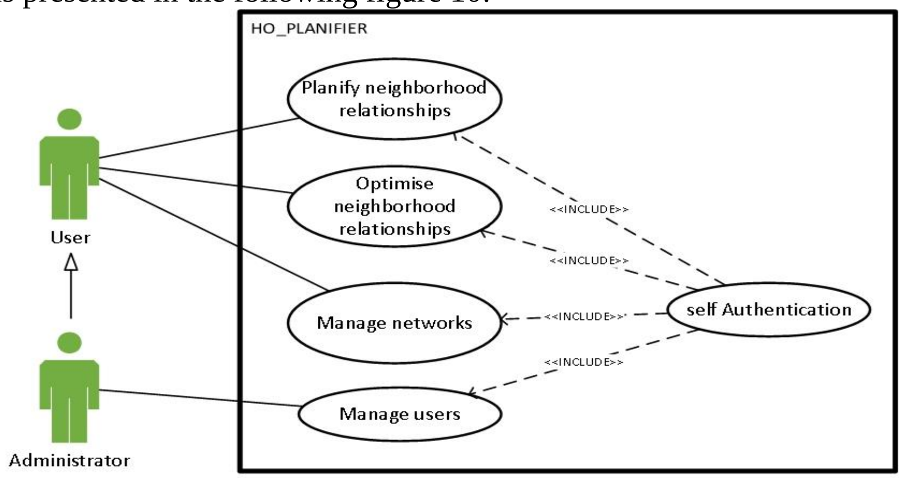

Figure 10. Use case diagram

3.4.4. Sequence diagram

The main objective of the sequence diagram is to represent the course of interactions between the objects involved in the system. It focuses on the chronology and order of messages exchanged, which helps understand how different parts of the system cooperate to achieve a desired result.

The neighborhood planning diagram is shown in Figure 11.

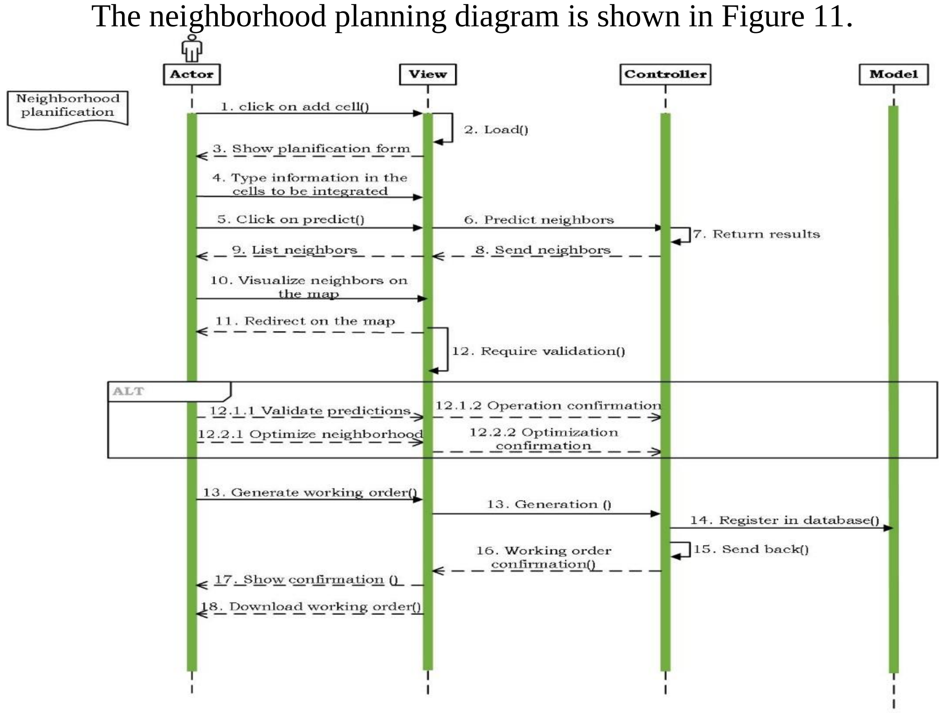

Figure 11.Sequence diagram for neighborhood planning

The Neighborhood Optimization Diagram is shown in Figure 12

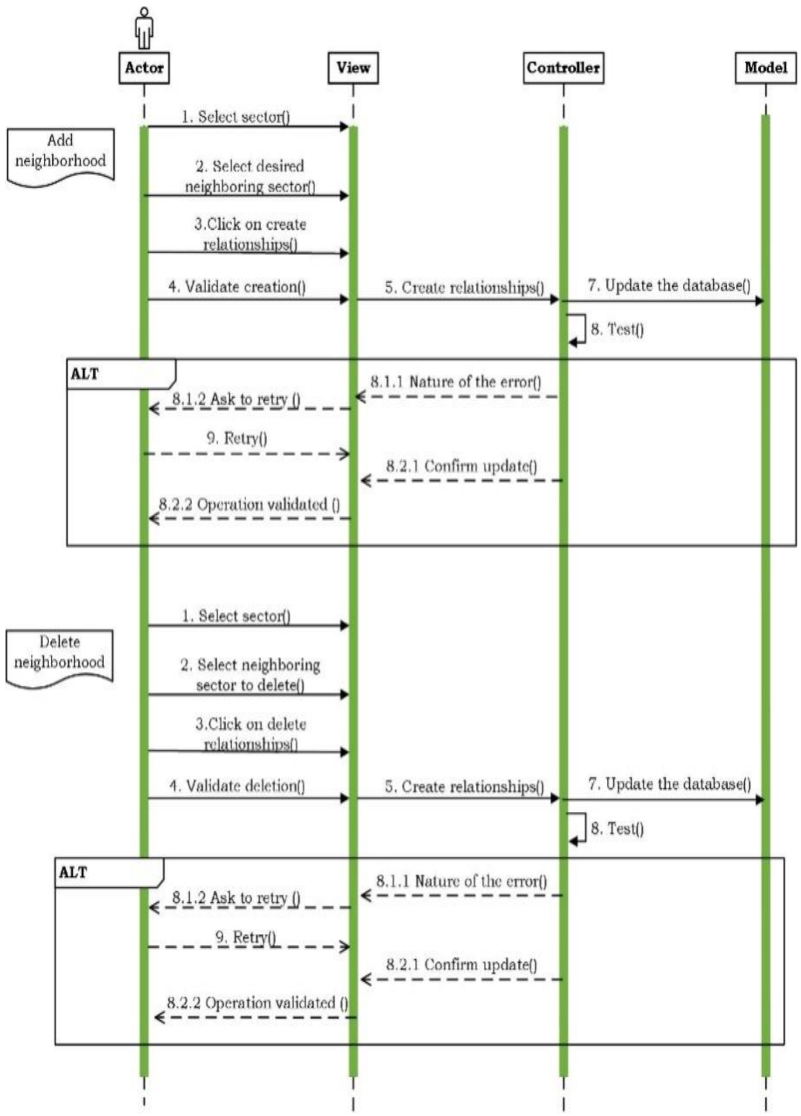

Figure 12. Sequence diagram for neighborhood optimization

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The Site Management Diagram is shown in Figure 13

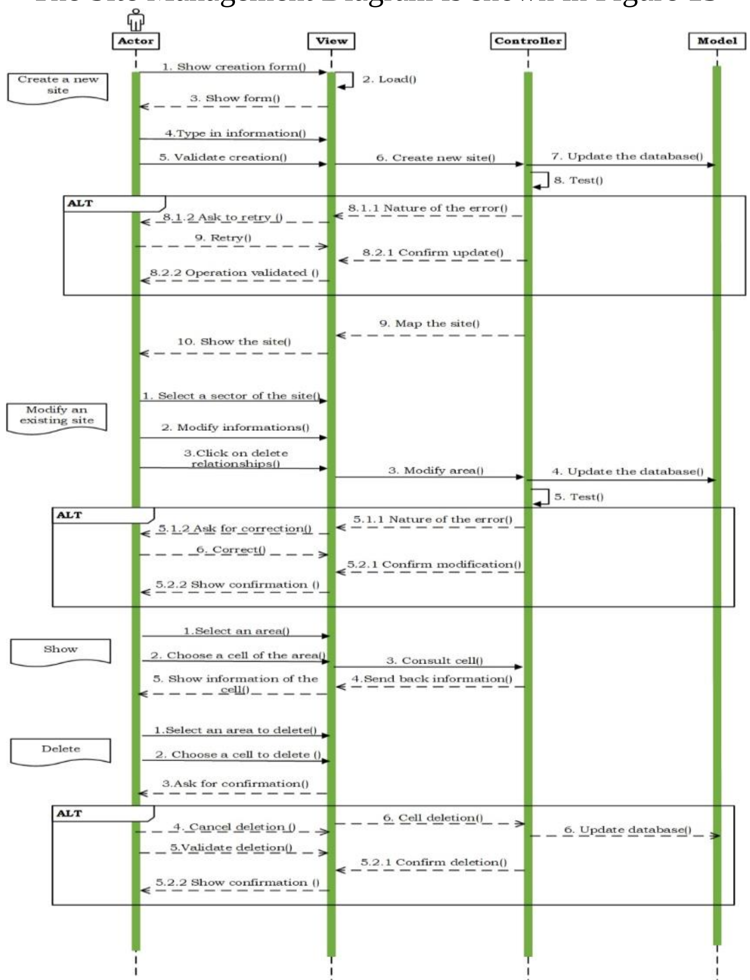

Figure 13. Sequence diagram for cell management

3.4.4. Class diagram

The classes used are:

- Site: contains the parameters of a BTS site;

- Sector: contains the parameters of the sectors of a site;

- Neighbors: contains for each sector, the list of its neighbors;

- User: contains all the useful information for a user of the system;

- Cell: contains the parameters of a cell which is attached to a “nature” subtable;

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- Mapping: contains map settings.

The class diagram is shown in figure 14:

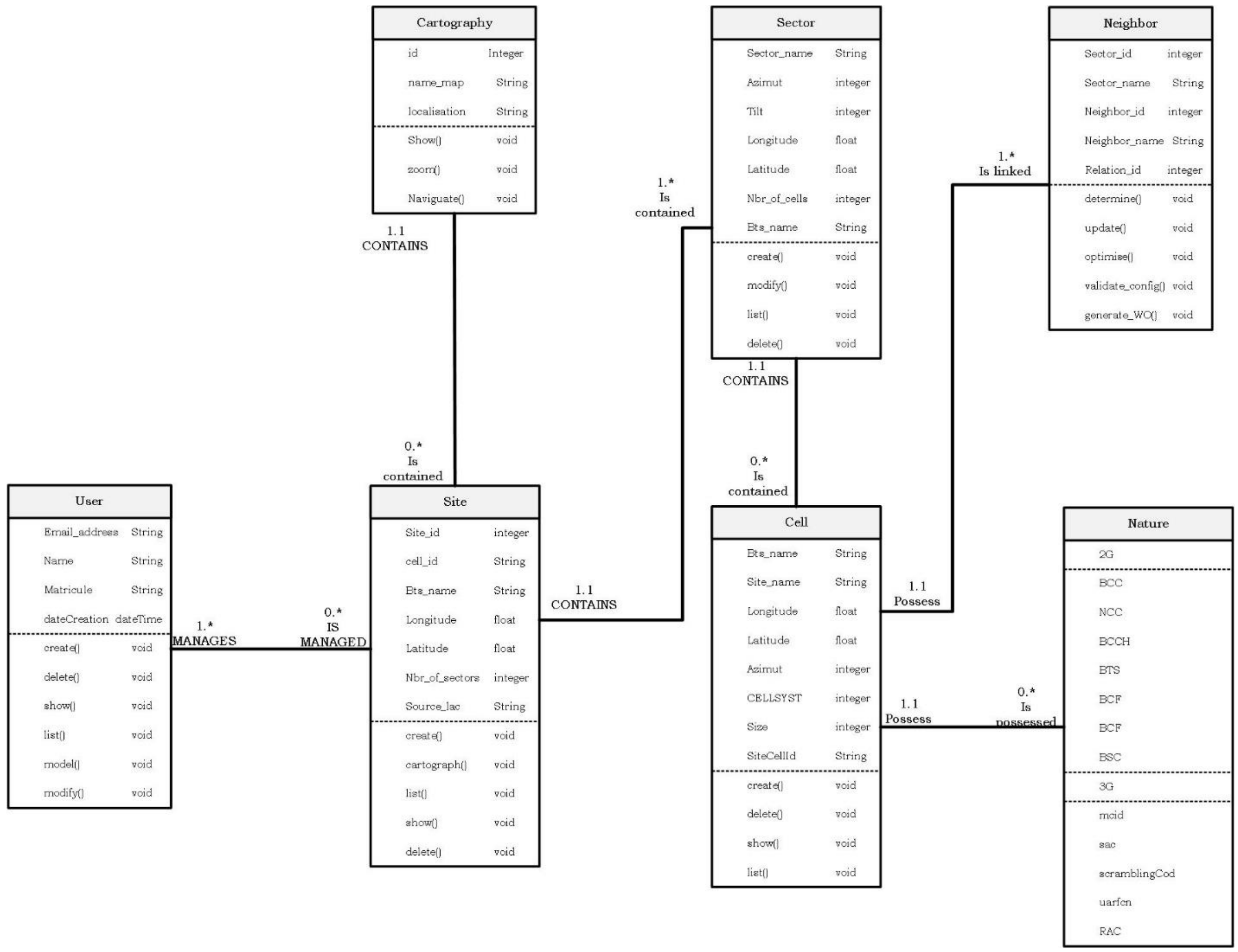

Figure 14. Class diagram

3.5.2 Development environment and tools

3.5.2.1 Visual studiocode

Visual Studio Code (VS Code) is an open-source code editor developed by Microsoft, widely used by developers to write and edit code in various programming languages.

3.5.2.2 XAMPP Control Panel V3.3.0

XAMPP Control Panel is a software application that allows you to manage and control the local XAMPP server. The latter is a suite of open source software including Apache, MySQL, PHP and other tools necessary for web development.

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3.5.3 Programming languages and libraries

3.5.3.1 PHPV8.1.6

PHP: Hypertext Preprocessor, better known by its acronym PHP (Recursive acronym), is a compiled programming language mainly used to produce dynamic Web pages via an HTTP server, but can also function like any locally interpreted language. PHP is an imperative language with full object model features since version 5.

3.5.3.2 Frame work Laravelde PHP

Laravel is an open-source web development framework in PHP that follows the MVC model. It provides a clear structure and pre-built features to ease the development process. With Laravel, you can separate business logic, presentation, and query processing, making your code modular and scalable.

3.5.3.3 Javascript

JavaScript (abbreviated JS) is a scripting programming language mainly used in interactive web pages but also on the server side. It is a prototype object-oriented language, that is to say that the bases of the language and its main interfaces are provided by objects which are not instances of classes, but which are each equipped with constructors allowing to create their properties, and in particular a prototyping property which allows them to create objects.

3.5.3.HTML

Hypertext Markup Language, commonly abbreviated HTML, is the data format designed to represent web pages. It is a markup language for writing hypertext, hence its name. HTML also makes it possible to semantically structure and format the content of pages, to include multimedia resources including images, input forms, and computer programs.

3.5.3.5.OpenStreet MAP

OpenStreetMap (OSM) is a collaborative online mapping project which aims to constitute a free geographic database of the world (allowing, for example, the creation of maps under a free license), using the GPS system and other free data.

3.5.4. Specifictools to machine learning

3.5.4.1.Python

Python is an interpreted object-oriented programming language. With its simple and readable syntax, it allows developers to quickly create applications in various fields such as web development, data analysis and artificial intelligence.

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3.5.4.2 Tensor flow

Tensor Flow is an open-source library developed by Google for machine learning and artificial intelligence. It allows you to create, train and deploy machine learning models, focusing primarily on deep neural networks.

3.5.4.3 Scikit-learn

Scikit-learn is a Python library used for machine learning, offering a wide range of algorithms and user-friendly tools for classification, regression, clustering, and other data analysis-related tasks.

3.5.4.4 Numpy

eNumPy is an essential Python library for numerical calculations and manipulation of multidimensional arrays. It offers advanced features, optimized mathematical operations and seamless integration with other libraries.

3.5.4.5. Pandas

Pandas is a library focused on manipulating tabular data. Pandas offers features for filtering, sorting, aggregating, merging, transforming and much more. Thanks to its ease of use and high performance, Pandas is a must-have library for processing and analyzing data in Python.

3.5.5. Global architecture of the system

The technological architecture on which the HO_Planifier platform runs includes three main components presented in Figure 15:

- A web server in which the web components of our system are deployed. He takes care of rendering the pages to clients.
- An application server: where the application components of the platform are deployed. It includes everything related to machine learning and data analysis operations.
- A database: where all the data necessary for the operation of the platform are stored.
- A REST API: for easy integration of AI models into the application.

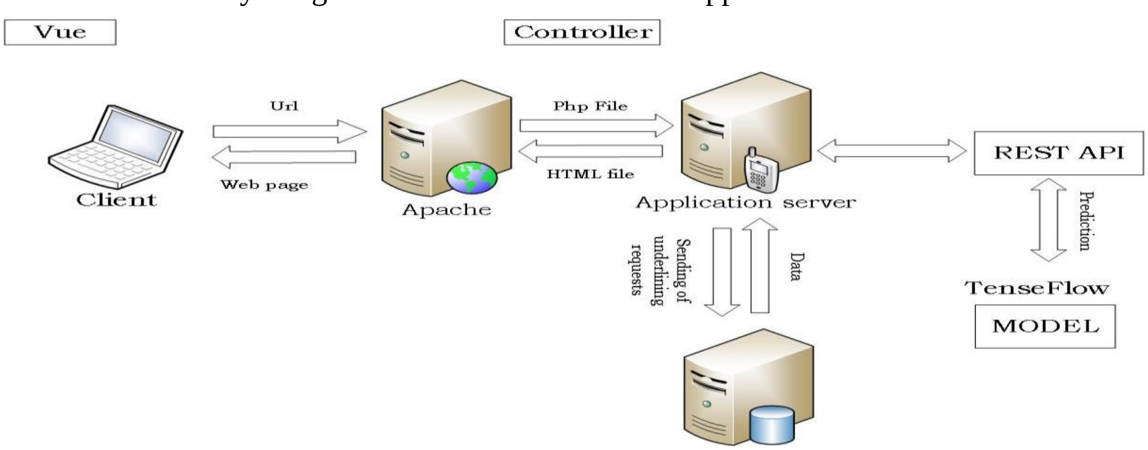

Figure 15. Application architecture

4. Results and Discussions

4.1. Tools presentation

4.1.1 Structural architecture

The tool is subdivided into 05 parts as illustrated in figure 16

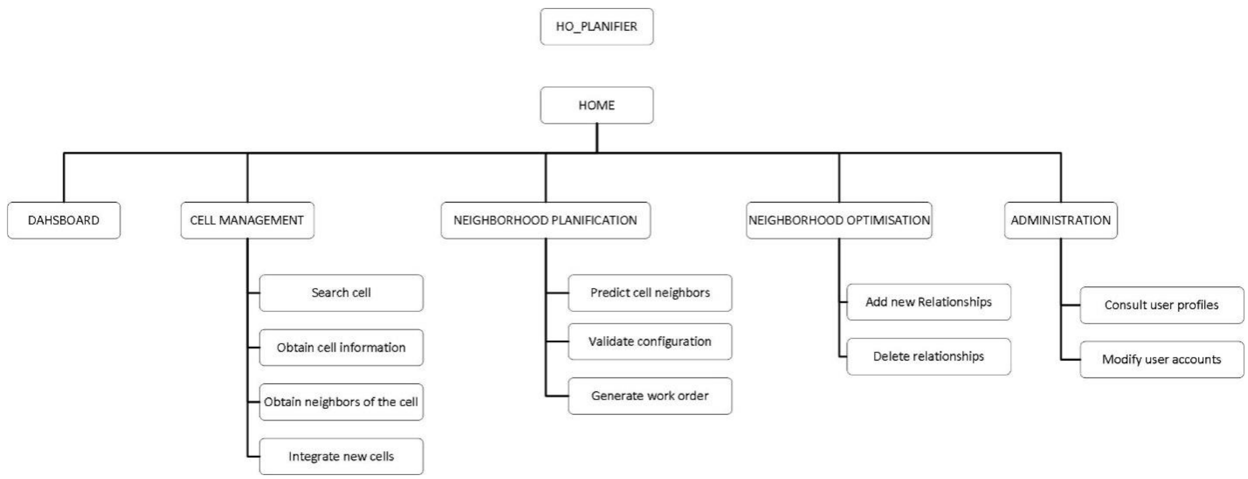

Figure 16. Structural architecture of the tool

4.1.3 Homepage: Dashboard

Once the user is logged in, they are redirected to the dashboard where the following elements are presented in Figure 17:

1: The number of sites in the OCM network;

2: The number of sectors in the network;

3: The number of cells in the network;

4: The number of users registered in the application;

5: The number of cells per category.

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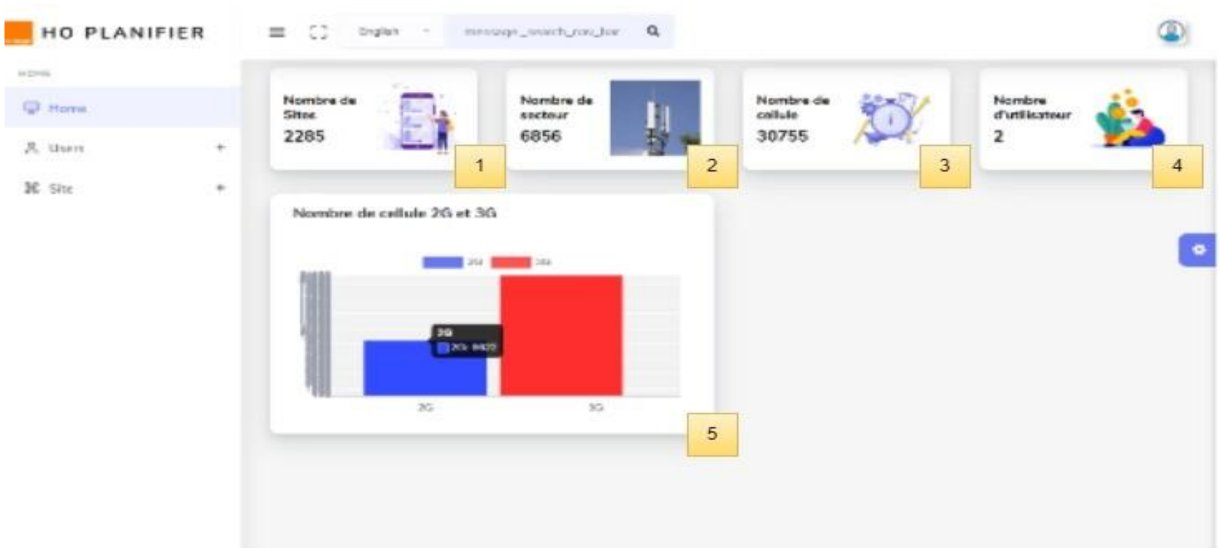

Figure 17. Dashboard

4.2. Functionalities presentation

4.2.1. Cell administration module

We present here how via the application, we can:

4.2.1.1 Show the neighborhoods of a cell

Further down in the drop-down menu containing the parameters of a cell, we list the different relationships specifying the characteristics of the neighbors and the relationship as shown in Figure 18.

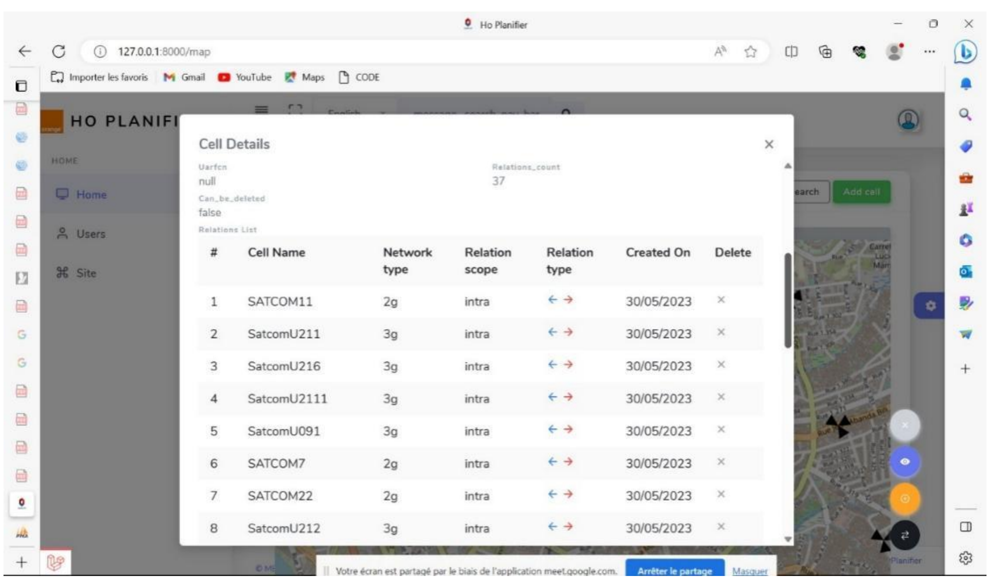

Figure18.The neighborhoods of a cell

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4.2.1.2 Integrate new cells into existing sectors

Here, as shown in Figure 19, engineers can decide to add a new cell to an already existing site for network optimization reasons.

We click on the “Add cell” button; in the site addition interface that appears, you fill in the different parameters of the cell in question.

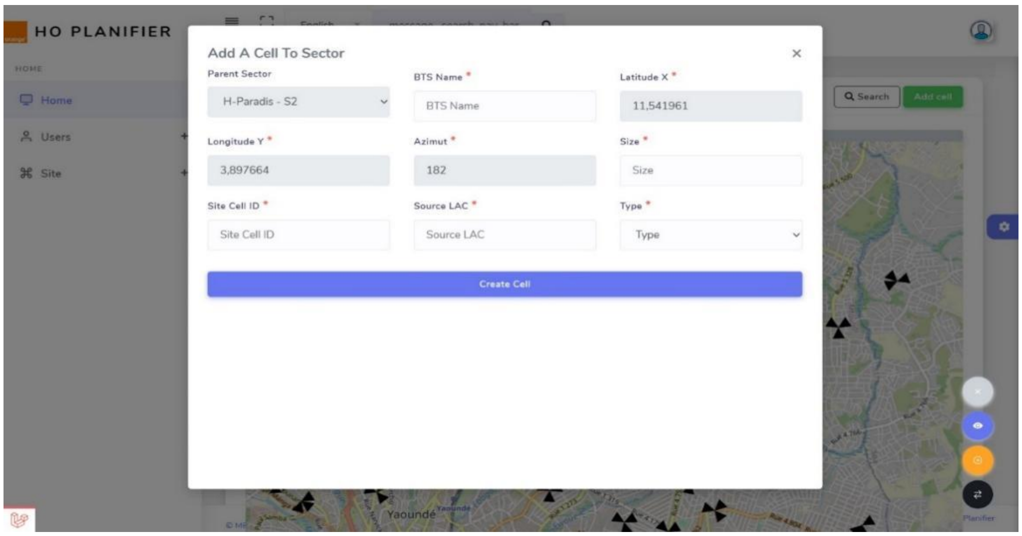

Figure 19. Add a cell

Add a new site on the map, visualize its neighbors and generate the associated configuration commands. To do this, you access the site manager by clicking on the “Site” button on the home interface. In the site manager.

4.2.3 Neighborhood planning module

This functionality is the main objective of our work. We present here how via the application, we can add a new site on the map, calculate its neighbors and generate the associated configuration commands. To do this, click on the Add cell and predict relationships button. In the site addition interface that appears, you fill in the different parameters of the site you want to integrate as shown in Figure 20

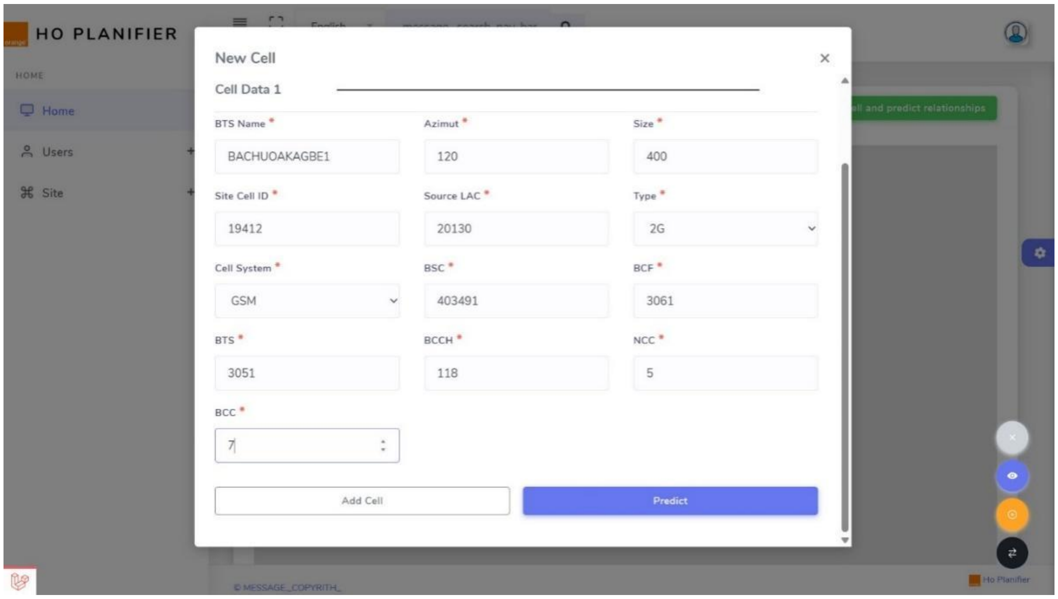

Figure 20. Prediction form

Then, simply click on the **Predict** button and the tool will directly detect the best possible neighbourhoods according to each category of relationships. Figure 21 clearly illustrates the procedure.

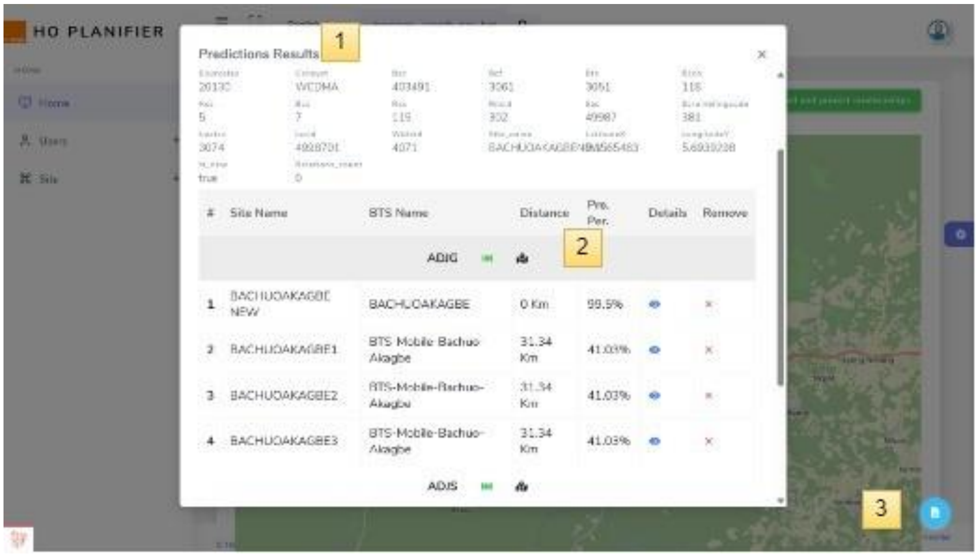

Figure 21. Prediction of he results

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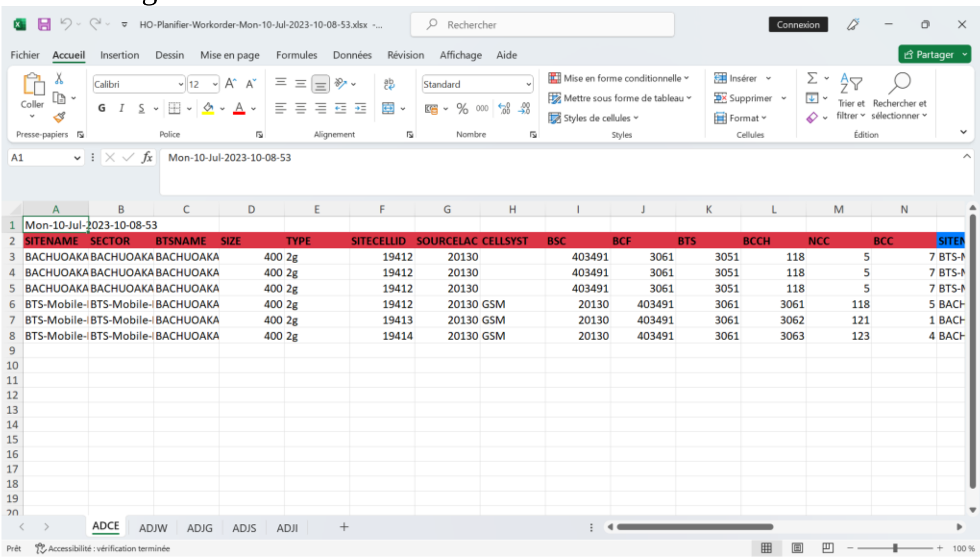
The legend associated with Figure 21 is as follows:
1: the form summarizes the characteristics of the integrated site;
2: the name of the prediction model used is specified and it is possible to return to the map to better visualize the proposed relationships;
3: In case of validation, you can directly generate the work order by clicking on the small blue button as shown in Figure 22:



Mon-10-Jul-2023-10-08-53

SITENAME	SECTOR	BTSNAME	SIZE	TYPE	SITECELLID	SOURCELAC	CELLSYST	BSC	BCF	BTS	BCCH	NCC	BCC	SITEN
BACHUOAKA	BACHUOAKA	BACHUOAKA	400	2g	19412	20130		403491	3061	3051	118	5	7	BTS-M
BACHUOAKA	BACHUOAKA	BACHUOAKA	400	2g	19412	20130		403491	3061	3051	118	5	7	BTS-M
BACHUOAKA	BACHUOAKA	BACHUOAKA	400	2g	19412	20130		403491	3061	3051	118	5	7	BTS-M
BTS-Mobile-I	BTS-Mobile-I	BACHUOAKA	400	2g	19412	20130	GSM	20130	403491	3061	3061	118	5	BACH
BTS-Mobile-I	BTS-Mobile-I	BACHUOAKA	400	2g	19413	20130	GSM	20130	403491	3061	3062	121	1	BACH
BTS-Mobile-I	BTS-Mobile-I	BACHUOAKA	400	2g	19414	20130	GSM	20130	403491	3061	3063	123	4	BACH

Figure 22. Work Orderextract

4.2.4 Neighborhood optimization module

Cevolet aétéconçupouraiderl'utilisateuràoptimiserlesrelationsdevoisinagesproposées parlesmodèlesintelligents. L'acteurpourraaubesoinsoitsupprimerdirectementunlienqu'il jugenonpertinentsoitenajouter.

4.2.3.1 Neighborhood creation

The legend associated with Figure 23 is as follows:

1: The tool only authorizes the creation of new neighborhood relationships;

2: The tool automatically imposes relationships between cells belonging to the same sector or site;

3: The "create relationship" button allows you to finalize the creation.

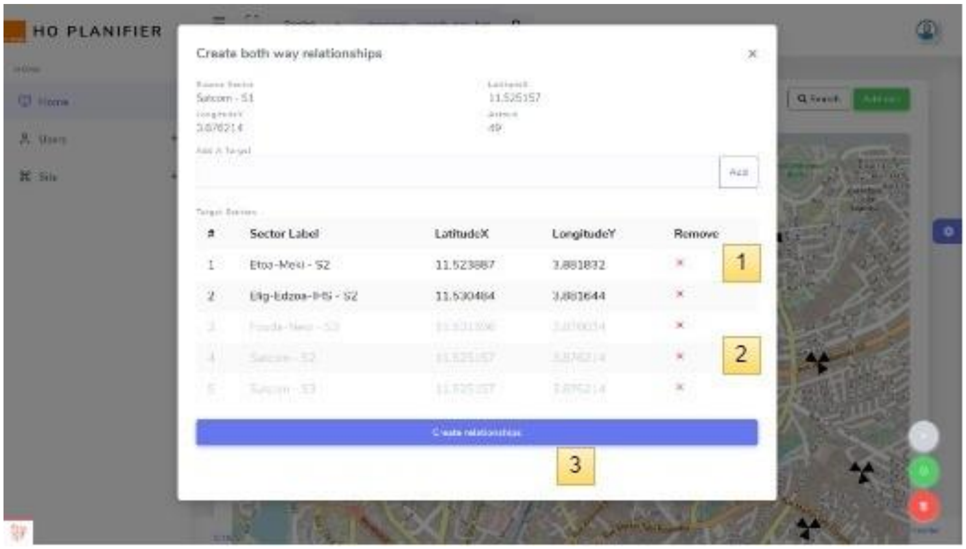


Figure 23. Neighborhood creation form

4.2.5 Administrator module

Accessible only by the system administrator, this menu allows you to manage the different users of the application. It therefore includes submenus for the creation, modification, display and deletion of users as shown in figure 24:

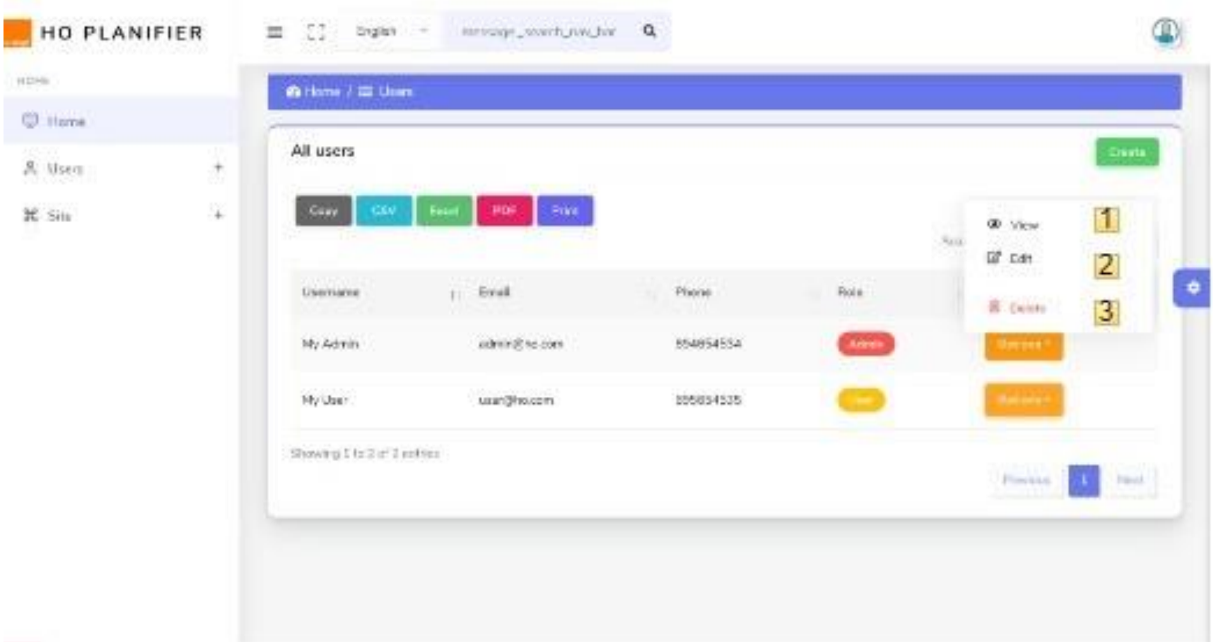
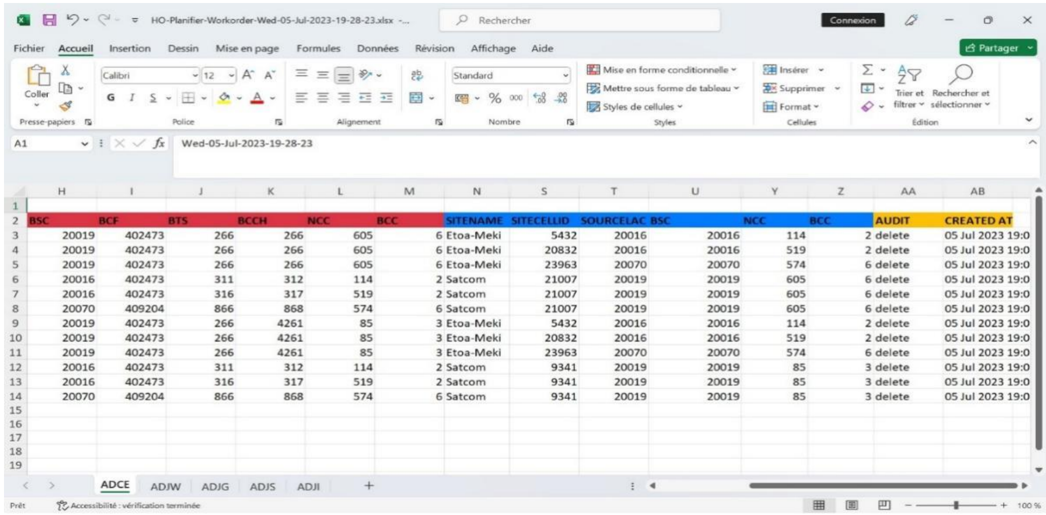


Figure 24. Administration

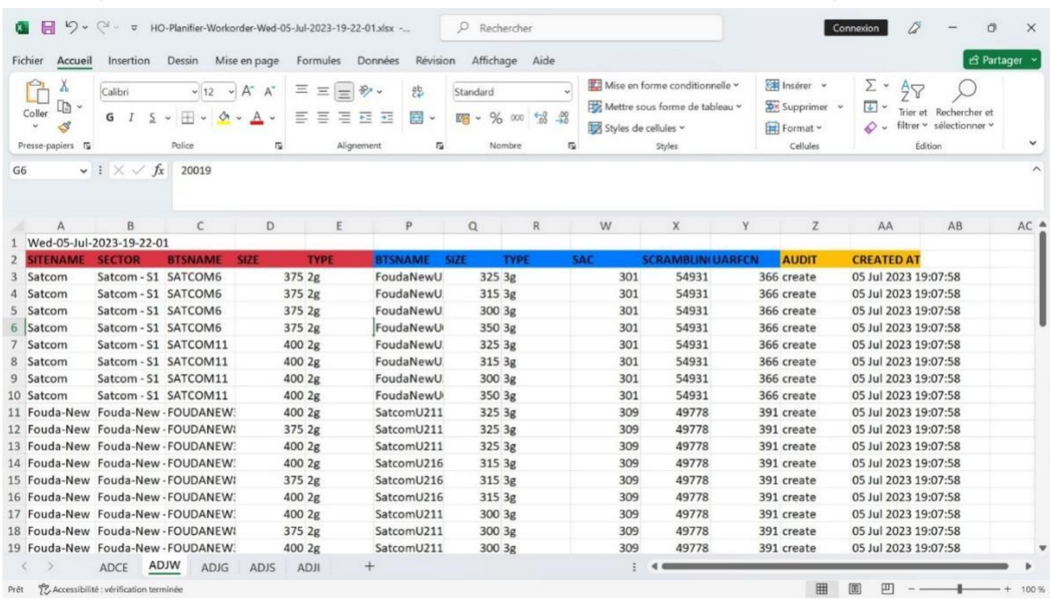
4.2.6 Generation of the final file

Once the configurations are completed, the final work order file will be automatically generated in the format implementable by NOKIA according to figures 25 and 26.



BSC	BCF	BTS	BCCH	NCC	BCC	SITENAME	SITECELLID	SOURCELAC	BSC	NCC	BCC	AUDIT	CREATED AT
20019	402473	266	266	605	6	Etoa-Meki	5432	20016	20016	114	2	delete	05 Jul 2023 19:0
20019	402473	266	266	605	6	Etoa-Meki	20832	20016	20016	519	2	delete	05 Jul 2023 19:0
20019	402473	266	266	605	6	Etoa-Meki	23963	20070	20070	574	6	delete	05 Jul 2023 19:0
20016	402473	311	312	114	2	Satcom	21007	20019	20019	605	6	delete	05 Jul 2023 19:0
20016	402473	316	317	519	2	Satcom	21007	20019	20019	605	6	delete	05 Jul 2023 19:0
20070	409204	866	868	574	6	Satcom	21007	20019	20019	605	6	delete	05 Jul 2023 19:0
20019	402473	266	4261	85	3	Etoa-Meki	5432	20016	20016	114	2	delete	05 Jul 2023 19:0
20019	402473	266	4261	85	3	Etoa-Meki	20832	20016	20016	519	2	delete	05 Jul 2023 19:0
20019	402473	266	4261	85	3	Etoa-Meki	23963	20070	20070	574	6	delete	05 Jul 2023 19:0
20016	402473	311	312	114	2	Satcom	9341	20019	20019	85	3	delete	05 Jul 2023 19:0
20016	402473	316	317	519	2	Satcom	9341	20019	20019	85	3	delete	05 Jul 2023 19:0
20070	409204	866	868	574	6	Satcom	9341	20019	20019	85	3	delete	05 Jul 2023 19:0

Figure 25. Extract from the OT for deletion of ADCE neighborhoods



Wed-05-Jul-2023-19-22-01

SITENAME	SECTOR	BTSNAME	SIZE	TYPE	BTSNAME	SIZE	TYPE	SAC	SCRAMBLIN(	UARFCN	AUDIT	CREATED AT
Satcom	Satcom - S1	SATCOM6	375	2g	FoudaNewU	325	3g	301	54931	366	create	05 Jul 2023 19:07:58
Satcom	Satcom - S1	SATCOM6	375	2g	FoudaNewU	315	3g	301	54931	366	create	05 Jul 2023 19:07:58
Satcom	Satcom - S1	SATCOM6	375	2g	FoudaNewU	300	3g	301	54931	366	create	05 Jul 2023 19:07:58
Satcom	Satcom - S1	SATCOM6	375	2g	FoudaNewU	350	3g	301	54931	366	create	05 Jul 2023 19:07:58
Satcom	Satcom - S1	SATCOM11	400	2g	FoudaNewU	325	3g	301	54931	366	create	05 Jul 2023 19:07:58
Satcom	Satcom - S1	SATCOM11	400	2g	FoudaNewU	315	3g	301	54931	366	create	05 Jul 2023 19:07:58
Satcom	Satcom - S1	SATCOM11	400	2g	FoudaNewU	300	3g	301	54931	366	create	05 Jul 2023 19:07:58
Satcom	Satcom - S1	SATCOM11	400	2g	FoudaNewU	350	3g	301	54931	366	create	05 Jul 2023 19:07:58
Fouda-New	Fouda-New -	FOUDANEW	400	2g	SatcomU211	325	3g	309	49778	391	create	05 Jul 2023 19:07:58
Fouda-New	Fouda-New -	FOUDANEW	375	2g	SatcomU211	325	3g	309	49778	391	create	05 Jul 2023 19:07:58
Fouda-New	Fouda-New -	FOUDANEW	400	2g	SatcomU211	325	3g	309	49778	391	create	05 Jul 2023 19:07:58
Fouda-New	Fouda-New -	FOUDANEW	400	2g	SatcomU216	315	3g	309	49778	391	create	05 Jul 2023 19:07:58
Fouda-New	Fouda-New -	FOUDANEW	375	2g	SatcomU216	315	3g	309	49778	391	create	05 Jul 2023 19:07:58
Fouda-New	Fouda-New -	FOUDANEW	400	2g	SatcomU216	315	3g	309	49778	391	create	05 Jul 2023 19:07:58
Fouda-New	Fouda-New -	FOUDANEW	400	2g	SatcomU211	300	3g	309	49778	391	create	05 Jul 2023 19:07:58
Fouda-New	Fouda-New -	FOUDANEW	375	2g	SatcomU211	300	3g	309	49778	391	create	05 Jul 2023 19:07:58
Fouda-New	Fouda-New -	FOUDANEW	400	2g	SatcomU211	300	3g	309	49778	391	create	05 Jul 2023 19:07:58

Figure 26. Extract from the OT for creating ADJW neighborhoods

5. Conclusion

At the end of this work, we proposed an intelligent tool for configuring neighborhood relations and integrating mobile radio sites with the practical case, the 2G/3G network of ORANGE CAMEROUN. The method used is based on deep learning. In fact, the use of deep learning allows for more advanced and precise analysis of data. By leveraging complex machine learning techniques, the tool can identify patterns, trends and hidden relationships between different base stations in the network. This leads to more efficient planning of neighbor relationships, thereby reducing interference and improving quality of service for subscribers.

Additionally, the tool offers increased flexibility and adaptability. It is able to adjust to rapid network changes, such as adding new base stations or changing a network site's settings. This ability to adapt guarantees continuous and optimal planning of neighborhood relations, even in a dynamic and evolving environment.

In perspective, it would be desirable in the future to develop optimization and statistical management modules to allow RAN engineers to immediately check the impact of the configuration on the quality of service of the network. Furthermore, we can associate this application with a planning tool in order to have very complete radio design software capable of detecting, analyzing and correcting any anomalies occurring in Handover relationships.

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