Frequency Channel Allocation to GSM network simulator

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Abstract

In a GSM network every antenna can have multiple frequency channels, which can range from 1 to 6. Every Carrier frequency in GSM is 200khz. While assigning frequency channels to the antennas in the network, there are multiple factors that need to be considered in order to have an optimized solution. The major problem in this project that is being addressed is interference, which can be occurred by the following parameters:

- **Distance between transmitters**
- **Geographical position**
- **Power of the signals**
- **Direction in which signals are transmitted**
- **Weather conditions**
- **Assigned frequencies**
- **Co-channel interference**
- **Adjacent-channel interference**

We considered all those parameters except for the weather conditions. The simulator assigns the frequencies to the antennas provided as inputs to the simulator.

Project Summary

There are a number of transmitters placed as per availability of area in GSM. Each transmitter is transmitting the electromagnetic oscillation of a certain frequency over the area covered by it. If electromagnetic oscillations of the same or higher powered adjacent frequencies collide, the level of noise increases significantly. Due to this effect, quality of communication decreases in certain areas.

The major parameters that need to be considered while assigning frequencies are:

Distance between transmitters:

The Distance between transmitters should be kept as far as possible, while adjacent frequencies or same frequencies are being used on those antennas.

Geographical position:

It is not possible to place the Transmitter as per convenience. There are major placing constraints because of city planning and availability zones.

Project Summary

The major parameters need to be considered while assigning frequencies are:

Power of the signals:

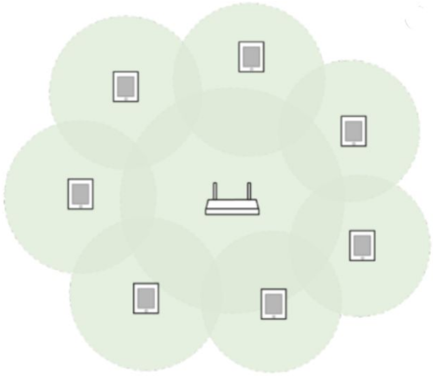
The more power provided to a certain frequency, it will cover more area. If the power of adjacent frequencies and co channel frequencies are more it will increase the noise. In this project, the radius of the transmitter is directly proportional to the power.

Direction in which signals are transmitted:

Direction of the antennas are mostly 360 degrees. In this project, there is only one possibility to set up a transmitter with an omni directional antenna. So, Coverage area will be 360 degrees.

Assigned frequencies:

The major controllable aspect of this project is strategically assigning frequency in order to achieve minimum interference between any pair of antennas. The frequencies available in the whole network are limited to the carrier company.



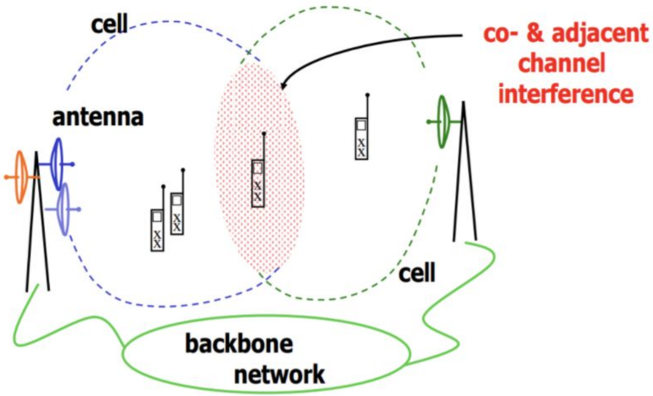
Project Summary

The major parameters need to be considered while assigning frequencies are:

Co-channel interference:

This Interference takes place when in some area two or more transmitters using the same frequency channel.

Co-channel interference is not actually an interference but more a sort of congestion.



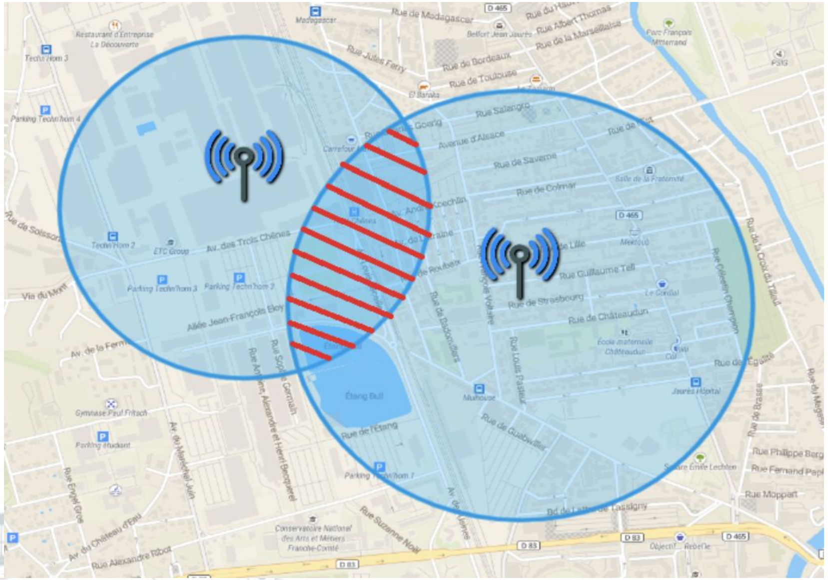
Adjacent-channel interference:

Signals which are adjacent in frequency to the desired signal cause adjacent channel interference. It is due to higher power in the adjacent frequencies.

Algorithm

To minimise the interference, this project proposes an algorithm. Which is as follows:

Step 1: Find which antennas' coverage zones are overlapping each other and make an overlapped matrix. To do this we need to check the distance between each antenna and radius of antennas.
To get this area overlapped , we developed an **equation**.



E.g. - 2 antennas A_1 and A_2
Coverage radius of R_1 and R_2
Area Overlapped between A_1 and A_2 : O_{12}
Distance between two antennas : D_{12}

$$\boxed{O_{12} = R_1 + R_2 - D_{12}}$$

This way we calculate O for all the combinations of antennas. And the sum of all antennas Area overlapped and got the coefficient of each antenna.

Algorithm

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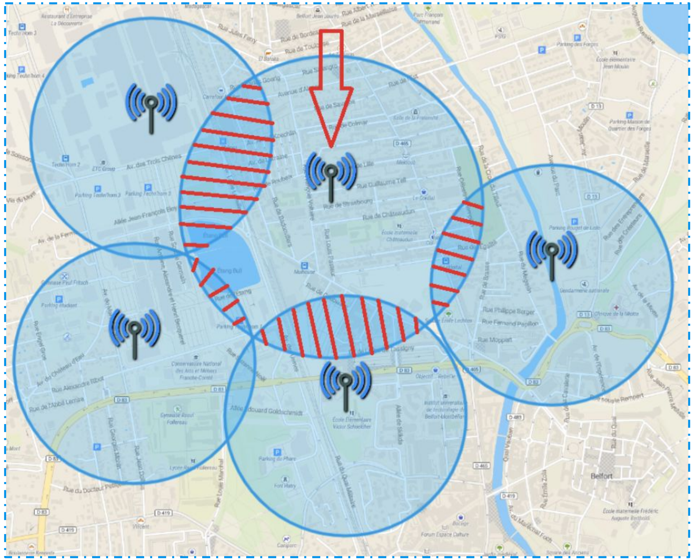
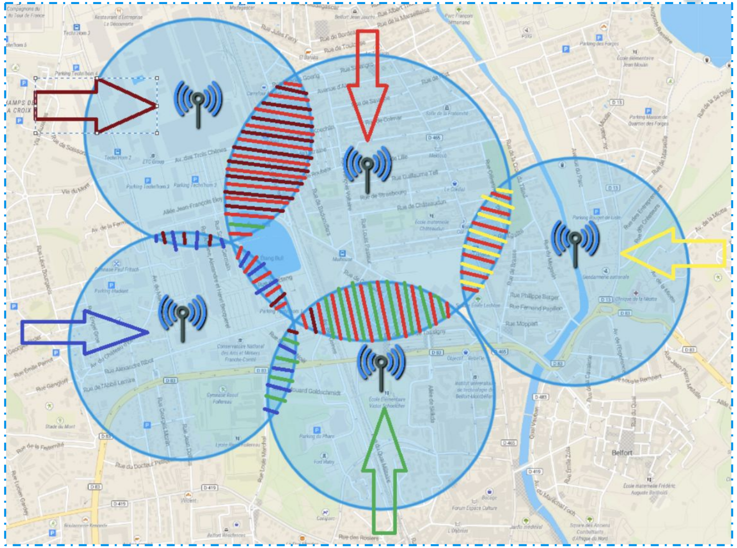


Step 2



Step 3

Step 4:

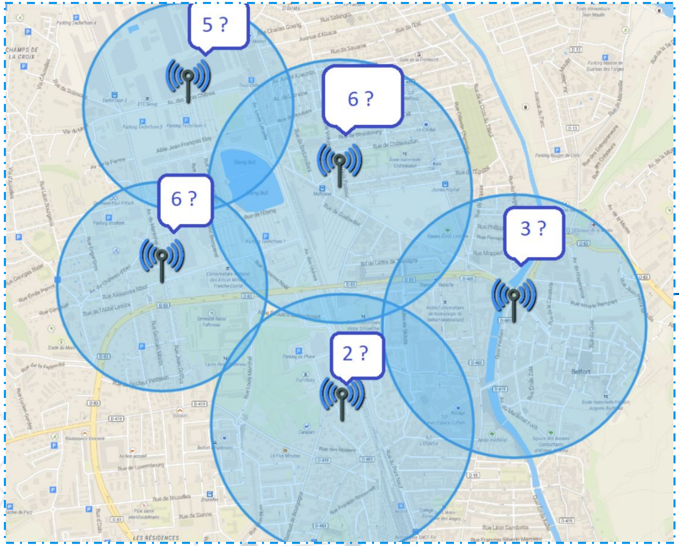
Check the total number of frequencies available for the whole network

Algorithm

To minimise the interference, this project proposes an algorithm. Which is as follows:

Step 5: Make the sequence of the frequencies with a gap of 2 frequencies. E.g.- (f1,f4,f7) or (f42,f45,f48). When the sequence reaches to the end it starts from 1st with a shift of one frequency with the same gap of 2 frequencies. E.g.: (if total frequencies are 60) - (f1,f4,...f58) or (f2,f5,...f59) or (f3,f5,..f60)

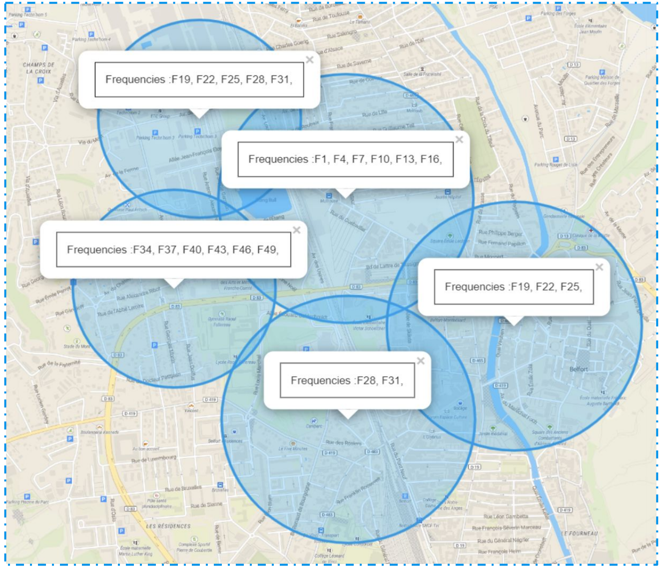
Step 6: Apply a greedy colouring algorithm for assigning frequencies as per requirement of each antenna.



For Greedy colouring algorithm,use a new sequence of antennas to colour. As per colouring algorithm every adjacent vertex should have a different colour. In this case every adjacent antenna will have a different sequence of frequencies.

Algorithm

To minimise the interference, this project proposes an algorithm. Which is as follows:



Step 7: Find the number of frequencies required for each antenna in a new sequence of antenna. And assign as per requirement.

Step 8: Calculate the interference between each antenna pair which has coverage overlap area.

From previous studies, this equation can be used to calculate the interference:

$$INT(f_i, d_i / f_j, d_j) = \frac{1}{\Delta d + \varepsilon} \times \frac{1}{\Delta f + \varepsilon}$$

Where,

i and j = any pair of antennas

fi and fj = List of frequencies assigned.

$\Delta\, d$ = Distance between two antennas

Δf = Distance between each frequency pair between two antennas

ε = bias number to not let denominator become zero

This project introduces a new equation that will consider the factors which affect the interference.

$$INT(f_i, C_i / f_j, C_j) = \frac{C}{\Delta f + \varepsilon}$$

i and j = any pair of antennas

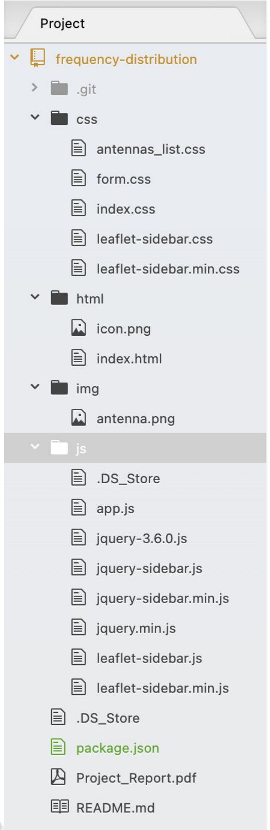
fi and fj = List of frequencies assigned.

$\Delta\, d$ = Distance between two antennas

C = Coefficient, coverage area overlapped.

ε = bias number to not let denominator become zero

Project Interface



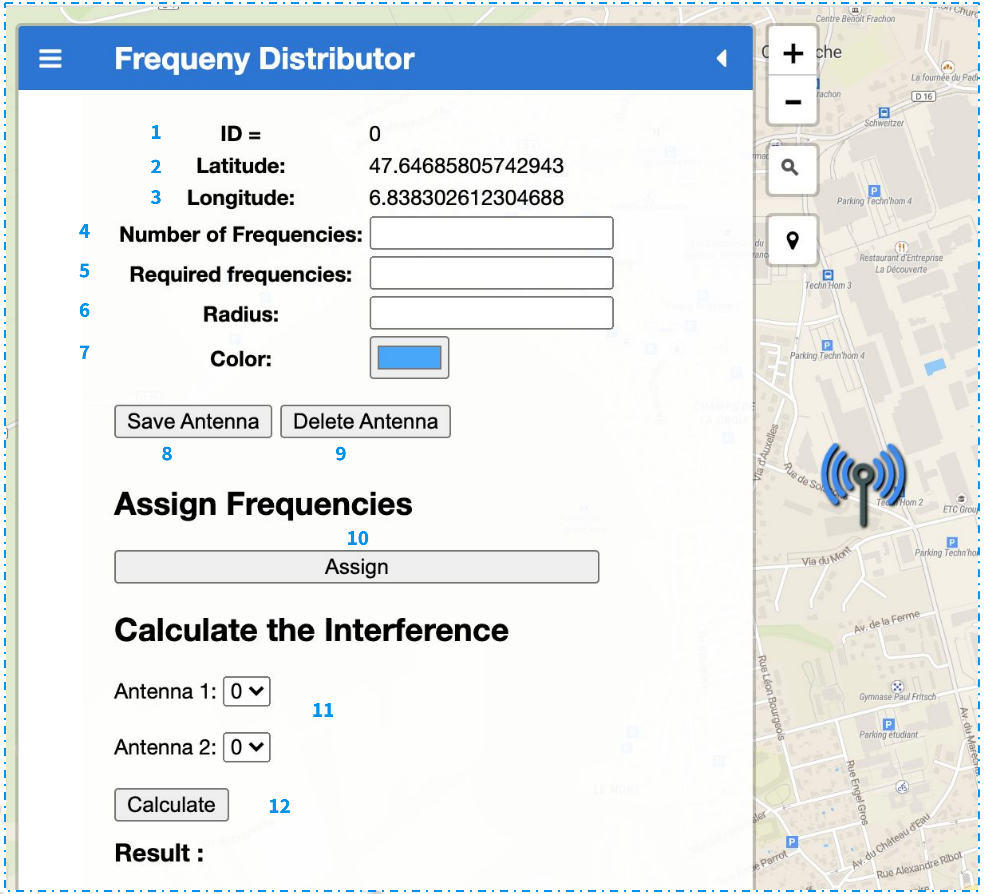
Structure

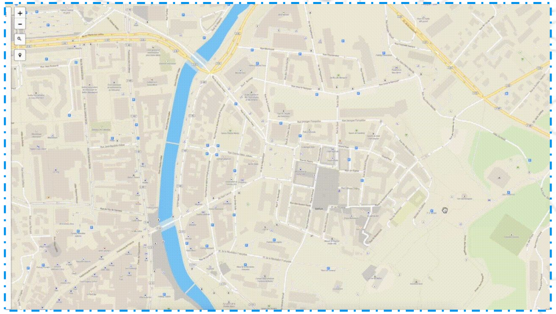
The main functionality is described in **app.js** file based on the open source JavaScript library Leaflet.

```
class Antenna {
  constructor(latlng) {
    this.id = -1
    this.lat = latlng.lat;
    this.lng = latlng.lng;
    this.radius = '';
    this.freq_num = '';
    this.circle = null;
    this.marker = null;
    this.res = []
    this.popup = null
    this.color = '#00a8ff'
  }
};
```

We have a class called Antenna with fields required to describe antenna's behaviour on a map.
The fields *circle, marker, popup and color* are used to show antenna and it's features on a map.
The fields radius, freq_num are set by a user, whereas the id, lat, lng are configured based on the addition order and the position on a map.
Array field res is used to save allocated frequencies for a fixed antenna.

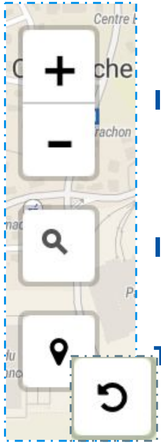
Project Interface





1. ID is configured based on addition order (0 for the first antenna)
2. Latitude - calculated based on the position on the map
3. Longtitude - calculated based on the position on the map
4. Number of frequencies - numerical input, describing number of all available frequencies >= 60
5. Required frequencies - numerical input in range [1, 6]
6. Radius - numerical value
7. Color - hex chosen from color grid
8. Save Antenna - button to save antenna configurations
9. Delete Antenna - button to delete antenna's configs and itself from the map
10. Assign - button to allocate frequencies
11. Dropdown lists to choose a pair of antennas
12. Calculate - button to display calculated interference between chosen pair of antennas

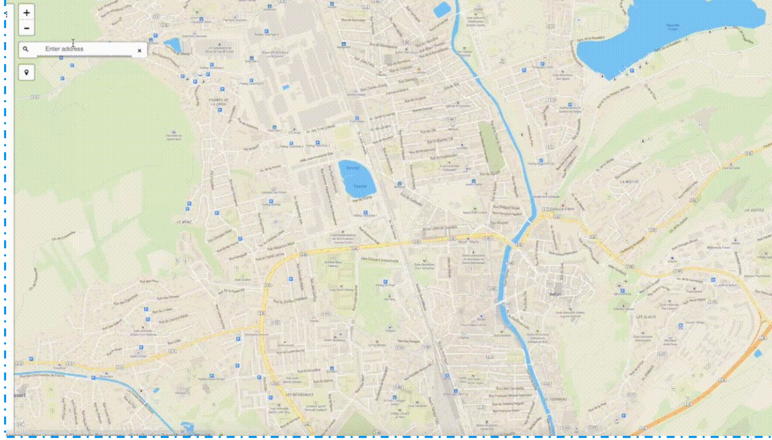
Project Interface



Icons to zoom in/out the map

Icon to search an address on the map and swith the position

Toggle icon to show/hide antennas' popups on the map



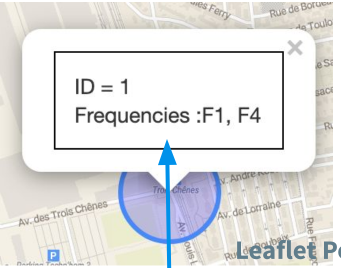
```
const search = new GeoSearch.GeoSearchControl({
  provider: new GeoSearch.OpenStreetMapProvider(),
});
map.addControl(search);
```

Leaflet Marker

```
antenna.marker = new L.marker(e.latlng, {
  icon: antennaIcon,
  contextmenu: true
}).on('click', showForm).addTo(map);
```

Leaflet Circle

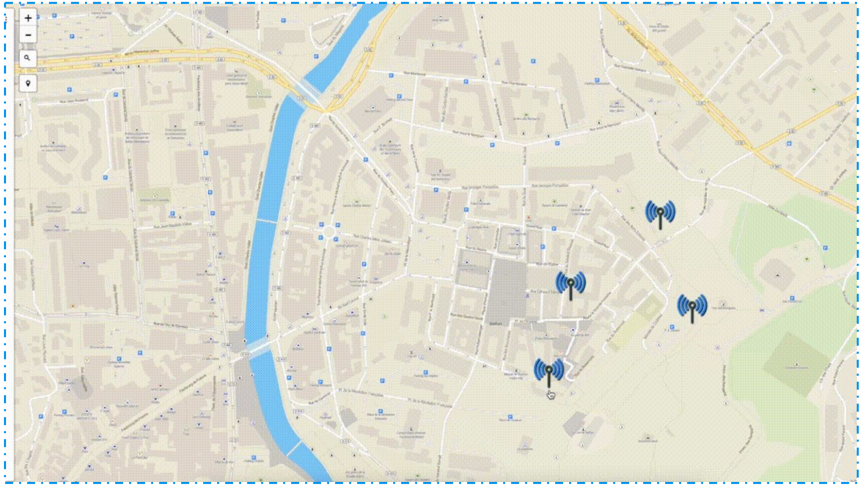
```
antenna.circle = L.circle([antenna.lat, antenna.lng], {
  fillColor: antenna.color,
  fillOpacity: 0.25,
  radius: antenna.radius
}).addTo(map);
}
```



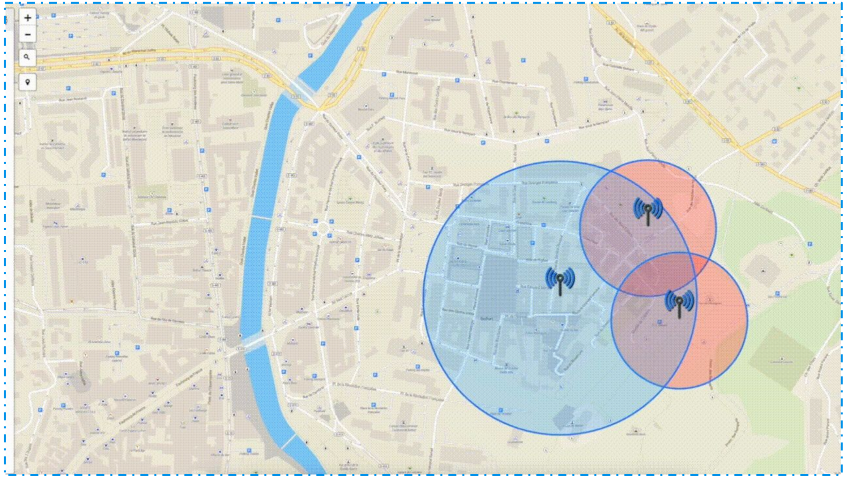
Leaflet Popup

```
antenna.popup = L.popup()
  .setLatLng([antenna.lat, antenna.lng])
  .setContent(html)
  .addTo(map)
  .openOn(map);
```

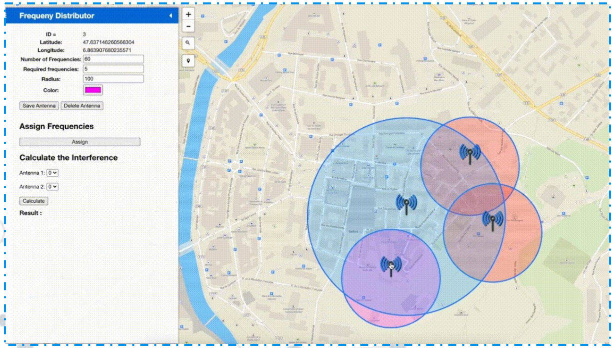
Project Interface



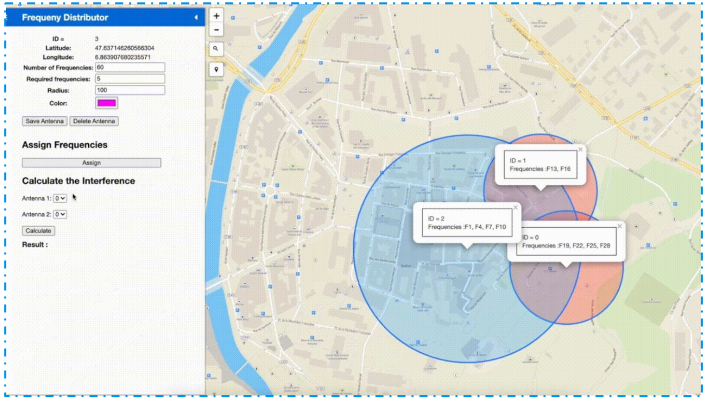
Sideboard appearance



Frequency allocation

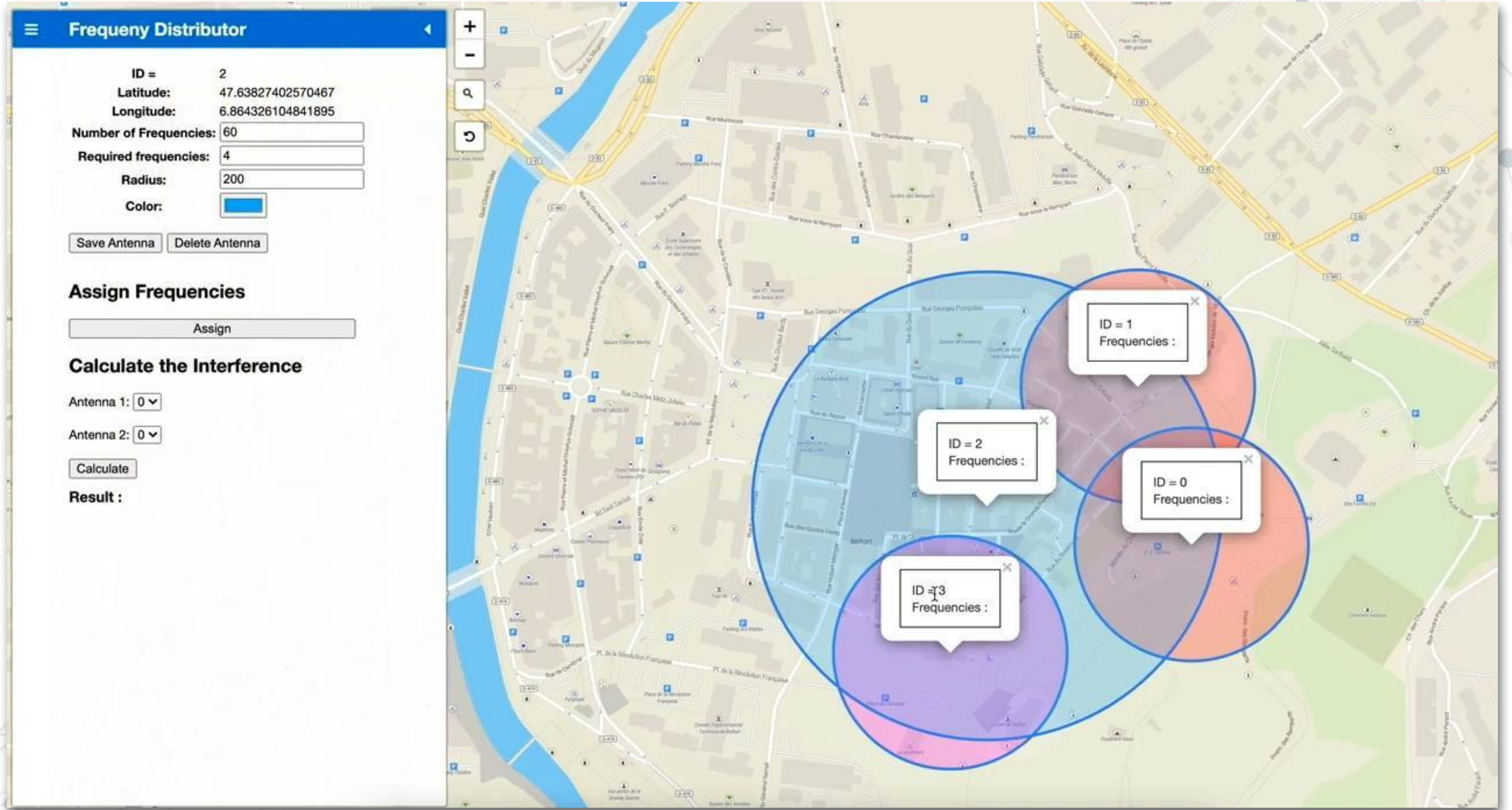


Antenna Deletinon



Antennas’ Interference

Project Interface



Sprints of work

Week 1	Understanding the basic concepts of GSM frequency Reuse from professor meetings. Background Study of the project by ourself. Searched for related reference papers and Previous Implementation.
Week 2	Started working on webApp with html and css. Setting up maps and adding the antennas to maps.
Week 3	Made an algorithm of calculation coefficient of each antenna using density of antenna network using javascript.
Week 4	Had a meeting with the professor, on issues of parameters for deciding frequency allocation . we had previous inputs calculated from our previous implementation. We moved to another implementation with a calculation of area overlapped with antenna coverage
Week 5	Made an update in javascript code with new way of calculating the coefficient of antenna. Started studying the implementation of the Greedy approach using this coefficient of antennas.
Week 6	Tried different ways of allocation of frequencies using hybrid way of using greedy and graph colouring algorithms on paper.
Week 7	Developed the best possible hybrid solution of greedy and graph colouring technique in order to solve this problem in an efficient way. And Modified the equation of calculating the interference between frequencies in order to get better results.
Week 8	Implemented this algorithm in javascript code. And Improved the GUI and showcased the output in a better way.

Conclusion

As per our observation and analysis, we can say that the algorithm proposed works very efficiently in order to minimise the interference. The best possible compromise in this solution has been introduced for complex situations like more than 10 antenna areas' are overlapped on every other antenna. Even in this kind of situation, algorithms perform well and provide the best possible outcome. The calculation of the interference is also more realistic than previously proposed by the other researchers.

Thank you!