Analysing 5G networks across the Netherlands and Switzerland

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5G networks are rapidly being deployed all around the world since 2019, due to the many benefits 5G provides compared to 4G networks. Some countries provide publicly accessible data about their 5G antenna network while others do not. This paper aims to provide an analysis of the 5G network of the Netherlands and Switzerland based on the available data. A framework is developed to analyse the differences and similarities of these countries based on the available data. The data that serves as input for the framework and analysis will be scraped from websites that contain data about 5G antennas shared by their government. In this data, the location, power level, frequency, etc. can be found. Furthermore, this paper aims to help 5G application providers get a better understanding of how the network in their country operates by giving a detailed analysis. Even though the networks are mostly similar in terms of the prioritisation of cities and the number of antennas per citizen, some minor differences were found and potential reasons for this are discussed.

Additional Key Words and Phrases: 5G network, Mobile Network Operators (MNO), 5G antenna, mmWave.

1 INTRODUCTION

5G, the fifth generation of wireless cellular networks, provides many benefits compared to the fourth generation such as higher data speeds, lower latency, more bandwidth, and higher availability. As overviewed in [1], many applications are now possible in 5G that would not have been possible on a 4G network. 5G provides these benefits because it makes use of mmWave technology among other things. As mentioned by [2], mmWave technology provides more network capacity in comparison to the previous generations of networks. However, the downside of mmWave technology is that the range of antennas is shorter compared to 4G for example. The space propagation loss of mmWave technology is much larger compared to lower frequency bands. This limits the range of 5G cells to approximately 100 metres in higher bandwidths. Because of the shorter range, it is important that 5G antenna placement is carefully planned out to provide sufficient coverage and speed.

Even though 5G networks are still relatively new, research is already being done about potential 6G networks, for example [3], which describes the road toward the deployment of 6G networks and concludes that there will be a need for a 6G network expected to deploy in 2030. This paper will investigate the 5G networks of the Netherlands and Switzerland. By analysing the 5G networks the differences and similarities of the countries can be identified and ultimately it could lead to improvements to the current network or for the potential deployment of 6G networks in the near future. Additionally, it provides 5G application providers an overview of how the 5G network in their country is deployed. There are several reasons why these countries are chosen. Firstly, the Netherlands has a lot of online information available about its 5G network. The government provides an overview of the locations of all the 5G antennas and their respective attributes. Moreover, Switzerland is chosen because they provide a similar map to the Netherlands. They show the locations of all of their 5G antennas. However, in comparison to the Netherlands, it seems to contain fewer data about the attributes of the antennas. Furthermore, the landscape of Switzerland differs considerably from the Netherlands, which might also be reflected in their 5G deployment.

Next to investigating the data about the deployment of the 5G network, also an analysis will be done about how the 5G spectrum is divided in different countries. This analysis serves to better understand the data and might support some of the claims that can be concluded from the data analysis.

The goal of this research is to find the differences and similarities of the 5G networks in the Netherlands and Switzerland based on the available data. This leads to the following research question: What are the main differences in the deployment of 5G networks in the Netherlands and Switzerland? The main research questions can be split up into multiple sub-questions to help reach an answer:

- RQ1: How do the countries divide their spectrum to MNOs?
- RQ2: What KPIs can be defined with the available data about the 5G networks of the various countries?
- RQ3: How do the countries score on several defined KPIs?

To address the mentioned research questions, we follow the following steps: a literature review, gathering data, define KPIs and create graphs. The literature review will analyse the spectrum division around the 3.5GHz bandwidth, similarly to [4]. The goal of analysing the spectrum division is to provide potentially useful background information for the data analysis. Furthermore, businesses can find out what the situation is regarding the spectrum for local 5G network users. A table is made similarly to Table 3.2 in [4], containing information about the Netherlands and Switzerland. After this, data is gathered for the data analysis. The data is gathered using a web scraper for the Netherlands and through an API for Switzerland. This data serves as input for the graphs that are later created. Afterwards, once the available data is gathered, KPIs are defined based on this. These KPIs form the basis for the graphs and the data analysis and are the answer to RQ2. Then graphs are created based on the already defined KPIs. These graphs show the main differences and similarities between the countries. Eventually, these graphs are used to answer the main research question.

2 RELATED WORK

Even though a large body of research has been conducted on 5G already, not much research has been done on the 5G network of countries. Matinmikko-Blue et al [4] describe how different countries consider emerging local 5G networks by analysing how the 5G

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Table 1. Spectrum assignment around 3.5GHz for NL and CH.

Element	**Netherlands**	**Switzerland**
Considered spectrum band	3.6 GHz, a total of 300MHz awarded. 3400-3540 MHz and 3750 - 3800 MHz are meant for local use.	3.5-3.8 GHz 300 MHz TDD
Spectrum assignment method	Market-based mechanism using SMRA auction.	Market-based mechanism using SMRA auction.
Pricing and results	Auction has not started yet and is delayed until October 2022. However, the other multi-band auction raised 1.23 billion EUR. Therefore a similar amount can be expected.	Swisscom paid 195,6 million CHF for 120 MHz. Salt paid 94.5 million CHF for 80 MHz and Sunrise paid 89.2 million CHF for 100 MHz of the bandwidth[5].
Stakeholder perspective and role of local 5G networks	Non-MNOs can also have access to the spectrum on assigned frequencies from 2026 onwards.	It is likely that Non-MNOs will also get access to part of the spectrum, however this is not yet mentioned anywhere.
Uniqueness of the case	98 percent of the surface of the country should be covered with a good 5G connection around the 3.5 GHz bandwidth [6].	MNOs should make 5G accessible to at least 25 percent of the population using their own infrastructure [5].

spectrum is divided by MNOs. The paper aims to connect business opportunities to local spectrum availability. They conclude that every country they analysed has a different way of dealing with assigning the spectrum to MNOs and the involvement of local businesses. This research forms the base for the first research question.

A prior study analyzes 5G networks in the Netherlands and provides a data analysis about the resilience of 5G networks [7]. It describes how mmWave technology might be impacted by natural disasters like heavy rain. In a way, it is similar to what this paper tries to achieve, which is performing a data analysis on a 5G network to draw conclusions about a 5G network.

Lastly, D. Janssen [8] also perform a data analysis on a cellular network. Even though the aforementioned study does not have similar research questions to this study, this paper did provide solutions to some of the problems that were encountered during this research, like how to allocate coordinates to cities.

3 SPECTRUM ANALYSIS

To get a better understanding of how the 5G networks is set up in the different countries we first perform a literature review on the spectrum division. Similarly to Matinmikko-Blue et al. [4] the spectrum around the 3.5 GHz frequency will be investigated, since it is a globally common band. The aforementioned paper analyses 5 different countries, however, not the Netherlands and Switzerland. The goal is to get a better understanding of how local businesses, like 5G application providers, can make use of the 5G spectrum. Next to the 3.5GHz band both countries also have bands around the 700 MHz and 26 GHz frequencies. The 700MHz band has been auctioned in both countries in a similar manner to the 3.5 GHz band. However about the 26 GHz band not a lot of progression has been made in implementation. The Dutch government will first auction the 3.5GHz frequency [6]. Furthermore, Switzerland does not grant licenses to MNOs for the frequencies around the 26 GHz band yet [9].

There are three types of spectrum assignment methods: Market based mechanisms, Administrative allocation and unlicensed commons. The Netherlands and Switzerland both make use of market based mechanisms, this means that the government auctions property rights on the spectrum. The auctions usually come with obligations and rules for the MNOs. For example, the Dutch government requires the MNOs who make offers on the auction to provide a good connection to their customers which covers at least 98 percent of the countries surface. Switzerland on the other hand, requires their MNOs to provide a 5G connection around the 3.5 GHz band to at least 25 percent of the population in 2024 according to [5].

The information displayed in Table 1 is mostly taken from [10], which is a website published by the European commission. The website gives a clear overview of the situation of the 5G network in the different European countries. There are some interesting notes to take away from this. First of all, the Dutch government requires 98 percent of the country to have a good 5G connection. According to [11], the goal is to get a 100 mbit/s internet speed for the entire country, this goal can be achieved through 5G. It is likely that the word 'good' is associated with at least 100 mbit/s. Secondly, it is not clear why the Swiss government has not assigned or mentioned anything about spectrum assignment for 5G application providers. However, according to [5] MNOs are obliged to give access to 5G application providers, but they speculate that this has already happened, but they assume that this information is not publicly available. On contrary, the Netherlands have already assigned a part of the spectrum to 5G application providers. Furthermore, both the Netherlands and Switzerland make use of an SMRA auction. This means that all of the spectrum bandwidth is auctioned simultaneously. It can be advantageous in comparison to other assignment methods like a CCA auction, because if on one part of the spectrum the bid is getting

Table 2. Available data for NL and CH.

Data	**Netherlands**	**Switzerland**
ID	Unique for every antenna.	Unique for every antenna.
Type	Type describes that the antenna is a 5G NR antenna.	Type is given the value 'point' for every single instance of an antenna.
Coordinates	Every antenna has X and Y coordinates, these coordinates are based on the Dutch system of RD-coordinates.	Every antenna has two coordinates, these coordinates are based on the Swiss system of LV95.
Antenna related information	This includes: the height of the antenna, the different angles of the antenna, the frequency of the antenna and the transmission power in dBW.	Switzerland only has data about the transmission power, which ranges from very small to large.

too high, MNOs can choose to bid on different parts of the spectrum.

In conclusion, both countries have a similar approach in their assignment of the spectrum around the 3.5 GHz band, namely a SMRA aucion. Both countries have a bandwidth of 300 MHz and make use of an SMRA auction. However, the Netherlands seem to have a more concrete plan on how local businesses should make use of the 5G spectrum. On the other hand, Switzerland might have plans of how they want to approach local businesses, but they have not publicised them [5].

4 SCRAPING DATA & KPIS

Before a data analysis can be done using Python, the data first had to be retrieved from the corresponding websites [12][13]. The data from the Netherlands had already been scraped by Lotte Weedage. The data was collected in a JSON format and was scraped from the antenna map website [12] using a Python script. The Swiss data was collected through the JSON API from the government website [13].

So now that all the data is collected, we have the following data available for analysis as shown in Table 2. As can be seen in the table, the data sets are similar in what it includes. At the time of writing, the data sets contain data about all the antennas available at the point of scraping the data. But it is important to note that the data set is still incomplete. With the availability of new 5G bands in the future and to aim for better coverage, new antennas are being built currently and will also be in the future.

The available data leads to the following KPIs:

- The number of antennas versus the population and surface area of the country.
- The percent of antennas in the most populated cities versus the rest of the country.
- The average power level of the antennas in the most populated cities versus the rest of the country.

It is important to mention that the data set for the Netherlands is limited, since also data about the MNOs operating the antennas could have been scraped. However, this data was not present in the provided data, but also would have been hard to compare to Switzerland, since it is unknown to the public which of the three MNOs operates which antenna in Switzerland.

5 DATA ANALYSIS

As mentioned, for the data analysis Python was used, in particular Pandas which is a package for data analyses. The goal of the data analysis is to find out how the deployment of the 5G network differs in the countries based on the available data. The code and corresponding data can be found on Github [14].

First of all, Switzerland has less antennas than the Netherlands. The Dutch data set contains 10970 antennas, whilst the Swiss only counts 7004. Therefore, the Netherlands most likely has better network coverage looking at the entire country, since the surface area of the countries is relatively similar. With the Netherlands having a surface area of 41.543 square kilometres and Switzerland having a surface area of 41.285 square kilometres. This means that an antenna in the Netherlands has to cover approximately 3,79 square kilometres on average. On the other hand, in Switzerland an antenna has to cover approximately 5,89 square kilometres on average. Of course this will only be the case if both countries strive to get 100 percent network coverage in their country.

As mentioned above, the antennas have to cover a relatively large surface area to reach full coverage. However, especially at the higher spectrum, the 5G signal gets weak quickly over a large distance from the antenna. Therefore, it is interesting to analyse how the placement of the antennas was prioritised. How many of the antennas are placed in population dense areas, versus how many are placed in the rest of the country. To create a graph showing this, first a couple of assumptions had to be made.

First of all, population dense areas had to be defined in both the Netherlands and Switzerland. We chose the 15 most important cities in both of the countries. In the Netherlands, these cities were chosen because they were the provincial capital or relevant (Enschede, Rotterdam). For Switzerland, the 15 most populated cities were chosen. The antennas had coordinates that marks their location, however a city does not have range of coordinates that define what

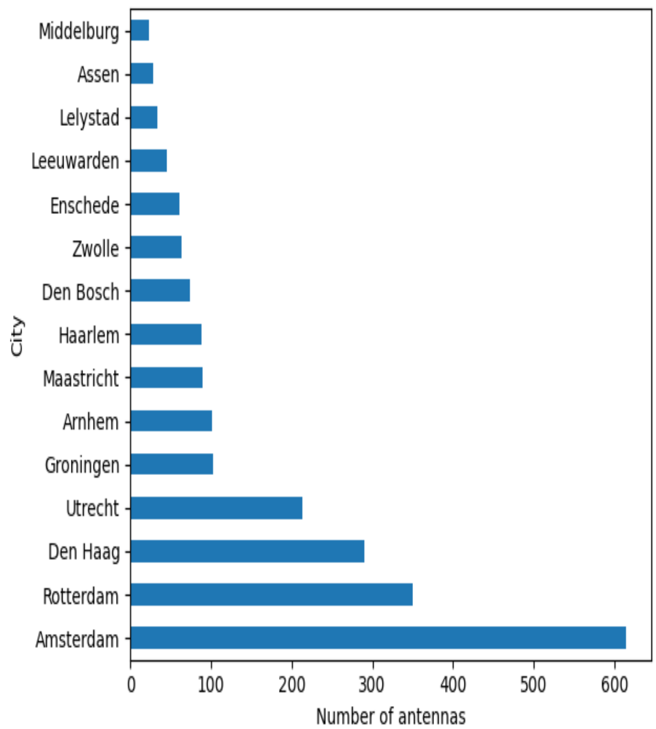

Fig. 1. Number of antennas in the major cities of the Netherlands.

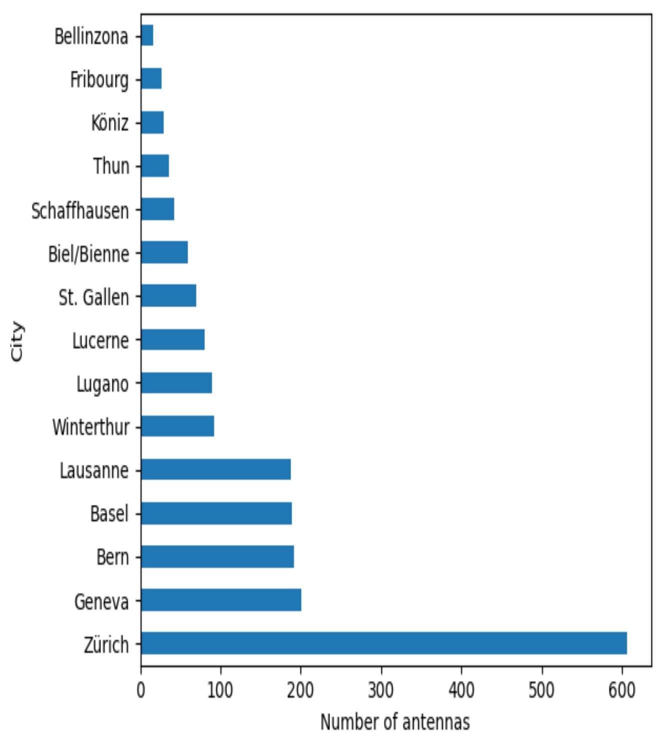

Fig. 2. Number of antennas in the major cities of Switzerland.

is in the city and what not. Therefore, a CSV file was made containing all of the cities that are analysed, their corresponding minimum longitude and latitude and their corresponding maximum longitude and latitude. Basically, it allocates an approximate square area to each of these cities. If the coordinates of an antenna are in the range of this square area, then the antenna is considered to belong to this city. We retrieve this information for the Netherlands from a study done prior [8]. The minimum and maximum longitude and latitude for the Swiss cities are taken by creating a square in Google maps, covering the entire city. The gathered data sets have different ways of noting down coordinates than latitude and longitude. So the CSV file was transformed to match the data sets. To transform the coordinates of the Dutch cities, the following website is used: https://www.gpscoordinaten.nl/converteer-rd-coordinaten.php. And for the Swiss cities, this website is used: https://www.swisstopo.admin.ch/en/maps-data-online/calculation-services/navref.html. The result is displayed in Figure 1 for the Netherlands and Figure 2 for Switzerland and is analysed in the next section.

5.1 Antennas vs. citizens

This section analyses the number of antennas per citizen, the aim is to give an overview of how population effects the placement and number of antennas in the countries. Moreover, we want to research if the major cities are prioritised during the deployment of the 5G network.

Firstly, the population of Switzerland and the Netherlands differ significantly. Switzerland has a total population of 8,637 Million in 2020, while the Netherlands has a population of 17,44 million in 2020. So the number of people per antenna in Switzerland is approximately 1234, while the number of people per antenna in the Netherlands is approximately 1590. So even though Switzerland has significantly less antennas, they also have less people that make use of them.

Figure 1 shows the number of antennas that are placed in the 15 major cities in the Netherlands, this corresponds to 2182 out of 10970 antennas. This means that 8788 of the antennas are placed in the less populated areas. This results in approximately 20 percent of antennas being placed in the major cities. These 15 cities accumulate a total of 3.929.180 citizens according to the CBS (1st Jan., 2022), which corresponds to approximately 23 percent of the population of the Netherlands. Therefore, it seems that the number of antennas in population dense areas seems proportionate and the major cities are not prioritised with respect to the rest of the country.

Figure 2 shows the number of antennas that are placed in the 15 major cities in Switzerland, this corresponds to 1918 out of 7004 antennas. Moreover, this means that 5086 antennas are placed in the rest of the country. This results in approximately 27 percent of the total number of antennas being placed in the major cities. In the 15 most populated cities of Switzerland a total of 1.673.639 people live. This corresponds to approximately 19 percent of the total population of Switzerland.

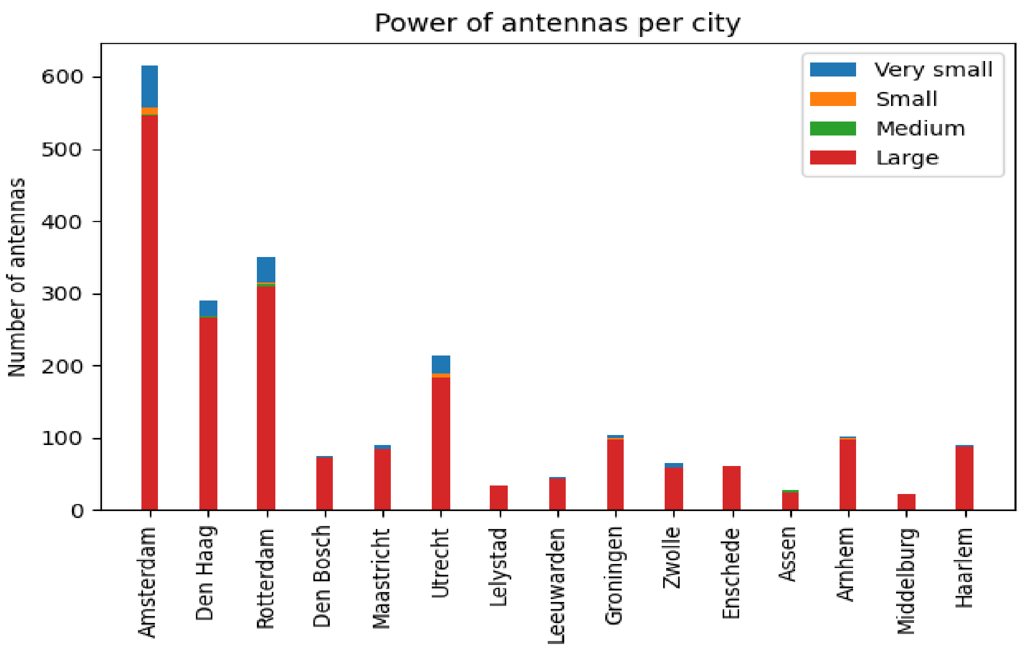

Fig. 3. Power levels of the antennas in the major cities of the Netherlands.

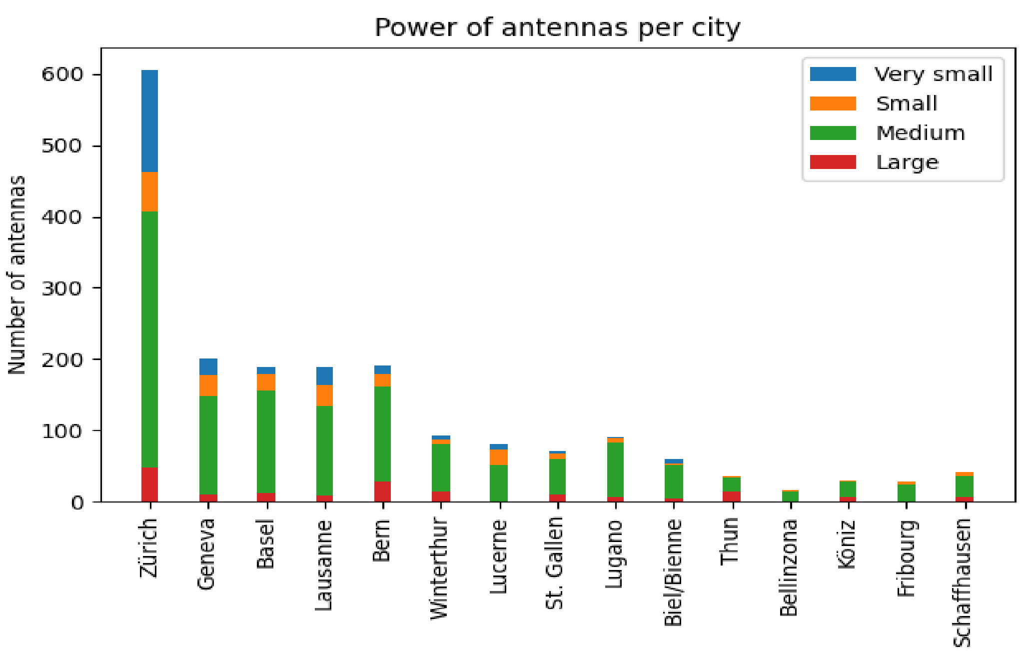

Fig. 4. Power levels of the antennas in the major cities of Switzerland.

When comparing the cities individually, the values for the Netherlands range from 1342 to 2789 citizens per antenna. Especially in the bigger cities in the Netherlands, e.g. Amsterdam, the number of people per antenna is relatively low compared to the smaller cities, e.g. Assen. The same applies for Switzerland, where in a city like Zürich, there are 696 people per antenna. While in Bellinzona, there are 2710 people per antenna. Therefore, it seems like both countries are prioritising the bigger cities compared to the smaller cities with the number of antennas being placed.

Based on this analysis, despite not differing significantly, we observe relatively more antennas in major cities in Switzerland in comparison to the Netherlands. However, since the population density of Switzerland is significantly lower than the Netherlands this is understandable. Therefore, the choice to prioritise the major cities where most people live is expected, rather than spreading out the antennas over the entire country in places where less people might live.

5.2 Power levels

This section will analyse the different power levels of the antennas in the Netherlands and Switzerland. The aim is to provide an overview of the differences in power level of the antennas. Furthermore, an analysis is done on the difference in power levels in the major cities compared to the rest of the country.

The power level of antennas in the Swiss data set is categorised in 4 categories: very small, small, medium and large. According to [15], the power levels are transmission power and mean the following:

- Very small: the total power of the antenna is between 1 to 10 Watt.
- Small: the total power of the antenna is between 10 to 100 Watt.
- Medium: the total power of the antenna is between 100 to 1000 Watt.
- Large: the total power of the antenna is more than 1000 Watt.

However, the Dutch data set has a different way of noting down the power levels, namely dBW. Therefore, this value is converted to Watts and after conversion the same scale and values as the Swiss data set are applied, so they can be compared.

It is remarkable that these values are exceeding the health and safety values set by ETSI [16] by a significant amount. It is unclear why this is the case, mostly because there is not a provided explanation about how the data should be interpreted. Especially the Dutch antenna map leaves the data up for interpretation, since it is scraped from the website, so no read-me file is provided at all. However, for Switzerland a brief explanation is provided by [15]. They state that for the calculation of the total radiated power all the individual antennas will operate at their maximum value, without taking into account the different directions of the antennas. Therefore, these values will always be higher than the real values. For the Netherlands no explanation is provided about how the values are calculated. The power levels of the antennas in the Netherlands could be the maximum transmission power the antenna could achieve, but not the power that is actually used in practice. We assume that the antennas are in compliance with health and safety regulations.

Figures 3 and 4 show the power levels of the antennas in the 15 major cities of the Netherlands and Switzerland respectively. The data about the rest of both the countries is left out of the graph for the sake of presentation. The first remarkable thing is that the graphs show a lot of different colour compared to each other. This is because the average power levels of the Dutch antennas is higher compared to the Swiss antennas. Most of the Dutch antennas are in the category large power, namely 10628 out of 10970 antennas. On the other hand, the Swiss antennas mostly fall into the medium power level, as 5028 out of the total 7004 are of this strength. No reason was found why the Dutch antennas have a higher power level than the Swiss antennas. However, it can be speculated that the Dutch network has higher requirements from the government, as 98 percent of the country should be covered by a good connection as mentioned in Table 1. Moreover, outside of the 15 major cities in Switzerland are most of the antennas with a large power level. As 912 out of 1071 antennas are outside these cities. A higher power level leads to more network coverage and outside of the cities there is a larger surface to cover. Moreover, we noticed that in the more populated cities, like Amsterdam and Zürich, there are more uses for the 'very small' antennas in comparison to the smaller cities, like Schaffhausen and Middelburg. In these cities the population density is larger, because of flats and other tall buildings. Therefore, we speculate that one 'very small' antenna might be able to provide a lot of people with a connection for a relative low cost for the MNO since it requires less power.

6 CONCLUSION

Since 5G is becoming increasingly relevant in society and 5G application providers are up and coming, it is helpful for them to understand how 5G in their country is deployed. This paper analyses the 5G network of both the Netherlands and Switzerland based on the available data. Even though the Netherlands and Switzerland differ a lot geographically, they have a similar approach in their deployment of 5G. However, there are some minor differences. Firstly, Switzerland had slightly more priority on the populated areas than the Netherlands. This is logical since Switzerland is less population dense than the Netherlands, so a larger percentage of people live in the major cities. Secondly, the Netherlands have a larger number of antennas than Switzerland, even though they have a similar surface area. But, since Switzerland has smaller population, they also have less people that make use of the network, therefore this balances out. Lastly, the average power level of the antennas in the Netherlands is much higher than that of Switzerland. In Switzerland the higher power level antennas are mostly placed outside of the major cities where they need to cover more ground.

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