



Independent Speed test Analysis of 4G Mobile Networks Performed by DIKW Consulting

Hugo Koopmans

07-01-2015

Contents

0.1	Colophon	4
0.2	Code generation	4
1	Abstract	5
2	Introduction	6
3	Step 1 : Data Collection	6
3.1	The raw data	6
3.2	Speedtest.net data	7
3.3	Sample test data from Ookla	7
4	Step 2: Data preprocessing	9
4.1	Basic data transformations	9
4.2	Suspicious devices	9
4.3	Top three operators	10
4.4	Focus on 4G technology	11
4.5	Operating systems	11
4.6	Geographical coverage area for 4G	12
5	Step 3: Data analysis	18
5.1	Histogram distributions	18
5.2	Box-plot	20
6	Step 4: Test design	23
6.1	Which statistical test do we need?	23
7	Step 5: Test results coverage area	25
8	Conclusion	26
9	Analysis and results Top 20 cities per city	27
9.1	Gemeente Amsterdam	29
9.2	Gemeente Rotterdam	30
9.3	Gemeente 's-Gravenhage	31
9.4	Gemeente Utrecht	32
9.5	Gemeente Eindhoven	33
9.6	Gemeente Tilburg	34
9.7	Gemeente Groningen	35
9.8	Gemeente Almere	36
9.9	Gemeente Breda	37
9.10	Gemeente Nijmegen	38

9.11 Gemeente Enschede	39
9.12 Gemeente Apeldoorn	40
9.13 Gemeente Haarlem	41
9.14 Gemeente Arnhem	42
9.15 Gemeente Amersfoort	43
9.16 Gemeente Zaanstad	44
9.17 Gemeente Haarlemmermeer	45
9.18 Gemeente 's-Hertogenbosch	46
9.19 Gemeente Zoetermeer	47
9.20 Gemeente Maastricht	48
9.21 Gemeente Unkown Location	49

0.1 Colophon

This analysis is performed by DIKW Consulting.

DIKW Consulting is a consulting firm that takes her customers on the path from Data to information to Knowledge to Wisdom. Our expertise is in the field of data logistics, data warehousing, data mining and machine learning.

T-Mobile has asked DIKW Consulting to perform this test as an independent third party. DIKW Consulting was paid to perform this test by T-mobile and has no other intentions then to perform this test by it's own high quality standards. The analysis was performed by generally accepted and approved standards and statistical methods using open source tools.

We let the data speak for itself.

If you have questions you can contact [DIKW Consulting](#). If you want to repeat this test by yourself you are welcome to do so, all necessary scripts are available on GitHub. The data is commercially available at [Ookla](#).

This analysis, method, tools and scripts are open sourced and placed on GitHub, see the read-me on the GitHub [repository](#).

For questions contact Hugo Koopmans at hugo.koopmans@dikw.com or +31 6 43106780

0.2 Code generation

This is an R Markdown document. Markdown is a simple formatting syntax for authoring HTML, PDF, and MS Word documents. For more details on using R Markdown see <http://rmarkdown.rstudio.com>.

1 Abstract

In this document we have conducted a statistical analysis of Ookla's NetMetrics data from speedtest.net. Ookla provides commercially available speed test data collected by their mobile app on the three main mobile platforms, Android, iOS and Windows mobile. We will load all the raw speed test data into a database, analyse the data of the top three operators(T-Mobile, Vodafone and KPN) and perform a test on how fast their respective 4G networks are. Our test will be on download speed, upload speed and latency(or ping).

The speed test data that is provided by Ookla's NetMetrics data from speedtest.net and obtained by T-Mobile is of October, November and December 2014. We will analyse and validate the data step by step. After investigation on suspicious testing circumstances, such as, but not limited to, devices, location, theoretical maximum speeds and specific dates the data is ready to be subjected to a significance test. This test will be done for all the data in the coverage area and for the biggest twenty cities in the Netherlands.

The result of these tests will give an answer to whether or not T-Mobile has on average a faster 4G network than Vodafone and/or KPN, based on the three metrics upload speed, download speed and latency.

2 Introduction

This document is a report of a statistical analysis of 4G network speed test data. The time period we consider is Q4 2014 so the months October, November and December of 2014 are in scope. We perform an analysis of [Ookla](#) NetMetrics Data data on three different measures:

- download speed
- upload speed
- latency(or ping)

On these metrics we compare the three major providers of 4G mobile networks in the Netherlands, Vodafone, KPN and T-Mobile.

This analysis is set up as follows:

- Step 1: Data Collection
- Step 2: Data preprocessing
- Step 3: Data analysis
- Step 4: Test design
- Step 5: Test results coverage area

In section 8 we provide the conclusion, and additionally the analysis and results of the Top 20 cities per city is presented in section 9.

3 Step 1 : Data Collection

The data was downloaded from Ookla servers by T-Mobile. For this analysis we use a PostgreSQL database that is locally installed.

The data is loaded from three different files, each file resembling a mobile platform (Android,iPhone and Windows mobile). The data is loaded as-is as it was received from the Ookla server. Scripts to load this data directly into a PostgreSQL database can be found in the [GitHub](#) repository.

All scripts to process the data are in SQL(available on [GitHub](#)) or R(included in this document, thanks to [knitr](#))

Let's get the data and do some basic counts.

3.1 The raw data

We load the raw files, downloaded from the Ookla server, into individual tables per mobile platform. In the table below we count the number of speed tests per mobile platform in Q4/2014.

	Counts
Android	168469
iOS	158498
Windows	8086
Sum	335053

Table 1: Raw test data counts

So we start this analysis with in total 335053 speed tests, which are represented as rows in the data set commercially downloaded from Ookla.

3.2 Speedtest.net data

Ookla designed their speed test in such a way that the results are as robust as possible. Ookla's speedtest.net is the de-facto standard for internet speed testing. According to <http://www.ookla.com/netmetrics>, NetMetrics is the choice of nearly every Fortune 500 ISP and Mobile Provider in the world. For more information please visit [Speedtest.net](http://www.ookla.com/netmetrics).

3.3 Sample test data from Ookla

Ookla has some random sample data available, this data can be used to validate our method. To validate the test result one would need the specific data of the Netherlands.

A sample set of Ookla NetMetrics data can be found [here](#). The files differ per mobile platform. The file descriptors for all three mobile platforms are listed below.

3.3.1 Android header descriptors

```
test_id - unique id of test in our system
device_id - unique device id in our system
android_fingerprint
test_date - YYYY-MM-DD HH:MM:SS in Pacific time (we can accommodate different time zones if needed)
client_ip - ip of client
download_kbps - download speed in kilobits per second
upload_kbps - upload speed in kilobits per second
latency_ms - ping in milliseconds
server_name - name of server tested to (name of city it is located in)
server_country - country name of server
server_country_code - country code of server
server_latitude - latitude of server tested to
server_longitude - longitude of server tested to
server_sponsor_name - sponsor name of server
client_country - country name of the client
client_country_code - country code of the client
client_region - region name of client (this will be state in the US)
client_region_code - region code of client
client_city - city of client
client_latitude - latitude of client (GPS or Maxmind when location services disabled)
client_longitude - longitude of client (GPS or Maxmind when location services disabled)
miles_between - miles between the client and the server tested to
connection_type - http://developer.android.com/reference/android/telephony/TelephonyManager.html
0=unknown, 1= Cell, 2=Wifi, 3=Gprs, 4=Edge, 5=Umts, 6=Cdma, 7=Evdo0, 8=EvdoA, 9=OnexRTT,
10=Hsdpa, 11=Hspa, 12=Iden, 13=Ehrpd, 14=EvdoB, 15=Lte, 16=Hsupa, 17=Hspap
isp_name - name of ISP (Maxmind)
is_isp - 0=Corporation/Academic, 1=ISP
network_operator_name - Mobile Carrier Name http://developer.android.com/reference/android/
/telephony/TelephonyManager.html#getNetworkOperatorName()
network_operator_code - MCC + MNC http://developer.android.com/reference/android/
/telephony/TelephonyManager.html#getNetworkOperator()
brand - http://developer.android.com/reference/android/os/Build.html#BRAND
device - http://developer.android.com/reference/android/os/Build.html#DEVICE
hardware - http://developer.android.com/reference/android/os/Build.html#HARDWARE
build_id - http://developer.android.com/reference/android/os/Build.html#ID
manufacturer - http://developer.android.com/reference/android/os/Build.html#MANUFACTURER
model - http://developer.android.com/reference/android/os/Build.html#MODEL
product - http://developer.android.com/reference/android/os/Build.html#PRODUCT
cdma_cell_id - http://developer.android.com/reference/android/telephony/cdma/package-summary.html
gsm_cell_id - http://developer.android.com/reference/android/telephony/gsm/package-summary.html
location_type - 0 = unknown, 1 = GPS, 2 = GeoIP
sim_network_operator_name - Mobile Carrier Name from the SIM
sim_network_operator_code - MCC + MNC from the SIM http://en.wikipedia.org/wiki/Mobile_Country_Code
```

3.3.2 iOS header descriptives

test_id - unique id of test in our system
device_id - unique device id in our system
test_date - YYYY-MM-DD HH:MM:SS in Pacific time (we can accommodate different time zones if needed)
client_ip - ip of client
download_kbps - download speed in kilobits per second
upload_kbps - upload speed in kilobits per second
latency_ms - ping in milliseconds
server_name - name of server tested to (name of city it is located in)
server_country - country name of server
server_country_code - country code of server
server_latitude - latitude of server tested to
server_longitude - longitude of server tested to
server_sponsor_name - sponsor name of server
client_country - country name of the client
client_country_code - country code of the client
client_region - region name of client (this will be state in the US)
client_region_code - region code of client
client_city - city of client
client_latitude - latitude of client (GPS or Maxmind when location services disabled)
client_longitude - longitude of client (GPS or Maxmind when location services disabled)
miles_between - miles between the client and the server tested to
connection_type - 0=unknown, 1=cell, 2=wifi, 3=GPRS, 4=Edge, 5=WCDMA, 6=HSDPA, 7=HSPA, 8=CDMA1x, 9=CDMAEVDORev0, 10=CDMAEVDORevB, 11=eHRPD, 12=LTE
isp_name - name of ISP (Maxmind)
is_isp - 0=Corporation/Academic, 1=ISP
carrier_name - http://developer.apple.com/library/ios/documentation/NetworkingInternet/Reference/CTCarrier/Reference/Reference.html#//apple_ref/occ/instp/CTCarrier/carrierName
iso_country_code - http://developer.apple.com/library/ios/documentation/NetworkingInternet/Reference/CTCarrier/Reference/Reference.html#//apple_ref/occ/instp/CTCarrier/isoCountryCode
mobile_country_code - http://developer.apple.com/library/ios/documentation/NetworkingInternet/Reference/CTCarrier/Reference/Reference.html#//apple_ref/occ/instp/CTCarrier/mobileCountryCode
mobile_network_code - http://developer.apple.com/library/ios/documentation/NetworkingInternet/Reference/CTCarrier/Reference/Reference.html#//apple_ref/occ/instp/CTCarrier/mobileNetworkCode
model - iPad, iPhone, iPod Touch
version - iOS version
location_type - 0 = unknown, 1 = GPS, 2 = GeoIP

3.3.3 Windows Mobile header descriptives

test_id - unique id of test in our system
device_id - unique device id in our system
test_date - YYYY-MM-DD HH:MM:SS in Pacific time (we can accommodate different timezones if needed)
client_ip - ip of client
download_kbps - download speed in kilobits per second
upload_kbps - upload speed in kilobits per second
latency_ms - ping in milliseconds
server_name - name of server tested to (name of city it is located in)
server_country - country name of server
server_country_code - country code of server
server_latitude - latitude of server tested to
server_longitude - longitude of server tested to
server_sponsor_name - sponsor name of server
client_country - country name of the client
client_country_code - country code of the client
client_region - region name of client (this will be state in the US)
client_region_code - region code of client
client_city - city of client
client_latitude - latitude of client (GPS or Maxmind when location services disabled)
client_longitude - longitude of client (GPS or Maxmind when location services disabled)
miles_between - miles between the client and the server tested to
connection_type - 0=unknown, 1=cell, 2=wifi, 3=GPRS, 4=1XRTT, 5=EVDO, 6=EDGE, 7=3G, 8=HSPA, 9=EVDO, 10=PassThru, 11=LTE, 12=EHRPD
isp_name - name of ISP (Maxmind)
is_isp - 0=Corporation/Academic, 1=ISP
carrier_name - AT&T, Verizon etc
manufacturer - Nokia, HTC, etc.
device_name - name of the device for e.g. "HD7 T9292"
hardware_version - device hardware version e.g. "1.0.0.0"
firmware_version - device firmware_version e.g. "1232.2107.1241.1001"
location_type - 0 = unknown, 1 = GPS, 2 = GeoIP

4 Step 2: Data preprocessing

In order to compare the data from the three different mobile platforms, we need to perform basic data transformations and merge it into one table.

Following that, in this preprocessing and analysis step we validate the data on the following points: 1. Are there any specific individual devices that perform a suspiciously high number of tests? 2. We apply filters so only the tests from the three operators we are interested in remain. 3. We apply filters so only tests done on 4G technology remain. 4. We are only interested in the coverage area in which all three operators claim to have 4G coverage. 5. We look at speed test results that are “too good to be true” that is, measured speeds that are above the theoretical maximum possible for that specific technology. We remove these speed tests. 6. We look at specific coordinates that are very frequent, depending on the explanation as for why these coordinates are used to often we remove or delete the speed tests per coordinate. 7. We look at specific dates that have a high number of speed tests for that day.

After all these checks we end up with a data set that is cleaned and ready to perform a statistical significance test on the investigated metrics.

4.1 Basic data transformations

As explained in section 3.3., the data from the three different mobile platforms comes in different formats and some basic data transformations are necessary before we can merge it into one table.

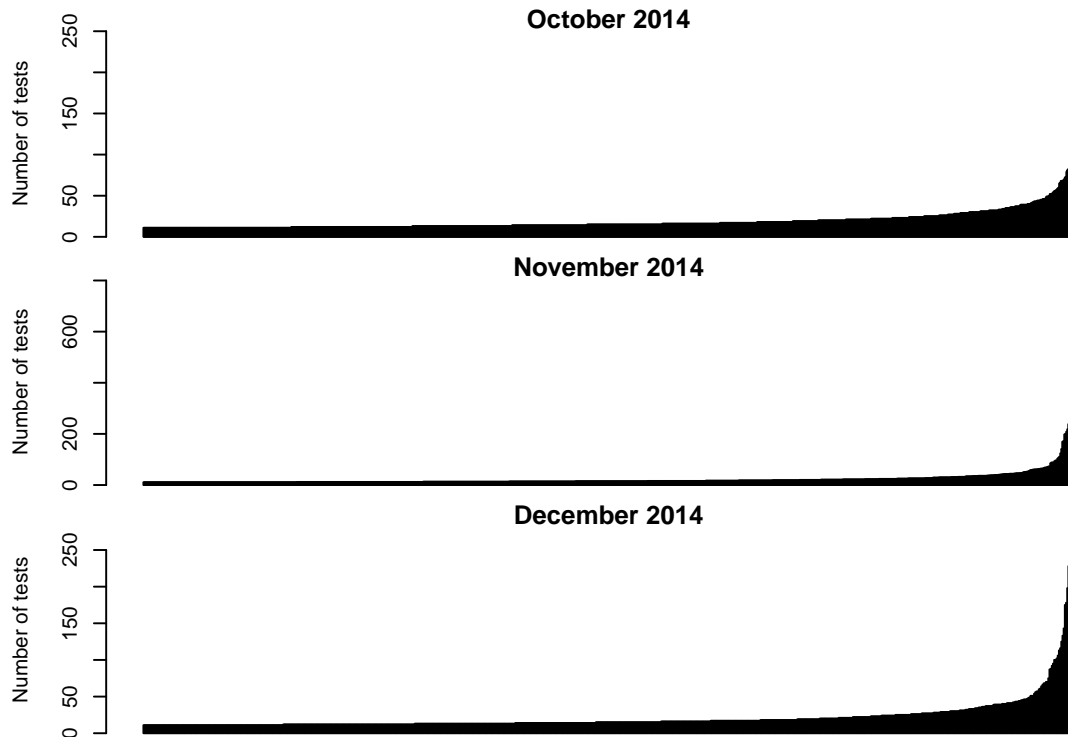
First of all, the names for the individual operators are spelled in various ways (e.g. ‘T-Mobile NL’, ‘T-Mobile NL’). Next, we need to map connection types to the specific technology used (2G, 3G or 4G) depending on the operating system of the device. For more details on these transformations, please see the SQL script on GitHub.

After these transformations are performed, we proceed with the checks and cleaning steps explained at in the previous section.

4.2 Suspicious devices

Are there any devices that perform tests very frequently?

In order to investigate this, let’s look at a frequency plot of devices that occur at least **ten** times in each month. On the right hand side we see devices that are used for testing very often, some of them even on an hourly basis. Obviously those devices are not in the hands of real customers so these will be removed from the data set.



Based on these plots and the amount of data consumed when performing a speedtest, we decide to remove specific devices that test more than 30 times a month. These devices are probably used by telecom professionals for testing purposes. The amount of data consumed per speedtest depends on the speed: the higher the speed, the more data is consumed. A test on 4G at very high speed can cost up to 100 MBytes per test out of the data bundle. So, 30 or more tests per month at high speed are equivalent to approximately 3GB of data usage just spend on tests alone and that is suspicious. The number 30 by itself is subjective, we could use 25 or 40 depending on what exact number of tests per device you would call suspicious.

Actually including these are not influencing the results significantly, but we want to use real customer data as much as possible, not affected by professionals testing their own (or others) network.

We identify 133 devices in October, 135 devices in November and 105 devices in December, which in total represent 20980 speed tests. After filtering these devices the data set has $335053 - 20980 = 314073$ speed test cases.

4.3 Top three operators

For this analysis we are only interested in the top three operators in the Netherlands. In the data set, at this point, there are 736 different operators identified. As we can see in the table below, in which we ranked the ten most used operators, most of the speed tests were performed by people using one of the three operators we are interested in. We will filter out all other operators and proceed with speed tests from these top three operators.

Operator	Number of speedtests
T-Mobile NL	91569
Vodafone NL	90178
KPN NL	83333
Telfort NL	4870
Carrier	4620
MY CELCOM	4173

Operator	Number of speedtests
TELE2	3070
Hi	1764
MY MAXIS	1547
VODAFONE TR	1520

Table 2: Most frequent operators

The top three operators together are good for 265080 tests conducted all over the Netherlands in the test period of Q4 2014. We keep only speed tests from the top three operators.

This leaves $314073 - 48993 = 265080$ rows in the data set.

4.4 Focus on 4G technology

In the raw Ookla Netmetrics data the variable called 'connection_type' identifies which technology is used, this variable can be transformed into the network technology used while performing the test.

The variable Connection type defines 4G as connection type 15 for Android. For iOS connection type 12 is LTE, and for Windows Mobile connection type 11 is LTE.

Definition of 4G for Android OS from the SQL script(available on GitHub) :

```
Case WHEN CONNECTION_TYPE=0 THEN 'UNKNOWN'
      WHEN CONNECTION_TYPE in (1,2) THEN 'WIFI/CELL'
      WHEN CONNECTION_TYPE in (3,4) THEN '2G'
      WHEN CONNECTION_TYPE=15 THEN '4G'
      WHEN CONNECTION_TYPE between 5 and 17 THEN '3G'
      ELSE 'UNKNOWN'
END AS TECHNOLOGY
```

Below we give an overview of the network technology types available in the data set.

	Number of cases	Percentage
2G	3890	1.47
3G	76065	28.70
4G	184356	69.55
UNKNOWN	3	0.00
WIFI/CELL	766	0.29

Table 3: Technology used in tests

In the remainder of this analysis we will focus on 4G technology.

Filtering on 4G technology leaves 184356 test cases in the data set.

4.5 Operating systems

For the top three operators we can look at the type of operating system used on these devices:

	KPN NL	T-Mobile NL	Vodafone NL
Android	38499	40024	39760
iOS	42941	50039	48207
Windows	1893	1506	2211

Most of the tests were conducted on an Android OS closely followed by iOS. Windows Mobile devices have limited representation in the data set. In this test we are not interested in testing the difference in performance per device or operating system.

4.6 Geographical coverage area for 4G

For this test to be fair to all three operators, we limit the comparison of the test to areas in which all three operators (KPN, Vodafone and T-Mobile) claim to have 4G coverage at the time of the measurements. While KPN and Vodafone already claim national 4G coverage, T-Mobile is still in the process of expanding their 4G network. Therefore, T-Mobile 4G coverage area is extended every month. This means that some areas only got 4G coverage during Q4 2014, the period of the test. In the per city analysis, this will be mentioned for the specific cities that only started to have 4G in the test period.

4.6.1 Coordinates with very high number of tests

Are there any locations, or coordinates, that occur very often in the investigated 4G area? If we join the coordinates latitude and longitude together and look at the most frequent occurrences we see that there are indeed some coordinates that are very frequent. How do these exact same coordinates end up in the data? To understand this we need to explain a bit more on how the Ookla Speed test application gets the coordinates from a mobile device([read more online](#)). There are several scenario's that can be the case: 1)The customer has approved the application access to the GPS coordinates of his/her device. 2)For some reason the app cannot read the GPS coordinates from the device at the time of the test. This reason can be of different origins, the user has blocked access or we are in a building or there are other technical reasons why the exact GPS coordinates cannot be accessed.

Whenever the exact coordinates are not available, due to measurement issues or because the customer is not allowing the application to use the GPS coordinates Ookla uses GEO-IP. GEO-IP is an online service to estimate the physical location of an ip-internet address (more online [from maxmind](#)).

Coordinates	Count
52.5 , 5.75	28572
52.3667 , 4.9	12516
52.35 , 4.9167	5318
51.9167 , 4.5	1628
51.8059 , 4.5634	491
52.0666 , 4.3209	241
52.0833 , 4.3	189
52.3666 , 4.9027	187
52.3667 , 4.65	157
52.0938 , 5.1191	143
52.352 , 4.8875	131
52.3881 , 5.2354	85
53.2167 , 6.55	67

Coordinates	Count
51.4408 , 5.4778	63
51.8425 , 5.8528	63

To understand more on how GEO-IP works we asked some specific questions to Ookla on these issues.

Coordinate (52.5-5.75) : Response from Ookla: *“The IP addresses associated with these tests show up as in the Netherlands, but that’s specific as it gets regarding GEO-IP. Were assuming that 52.5, 5.75 is the Dutch equivalent of the middle of Kansas (in the US if GEO-IP Cannot be determined it defaults to the center of the US which in our case is Kansas). All it knows is it’s in the Netherlands, so GeoIP specifies the center of the country.”*

Coordinates (52.3667-4.9) and (52.35-4.9167) are both in Amsterdam, but in one case the latitude is with less precision and in the other the longitude. Question to Ookla: Can we still assume the measurements are from Amsterdam? Response Ookla: *Yes, GeoIP is used here. We can assume you are in Amsterdam but like any other GeoIP location result, the confidence level isn’t as high as it would be if we were able to get location information directly from the device, meaning if we were able to obtain GPS instead of GEO-IP.*

Coordinate (51.9167-4.5) is in Rotterdam. Again with limited precision, same response as above from Ookla.

Coordinate (52.0666-4.3209) is in The Hague. All cases are tests with operator equal to “T-Mobile NL” also this location is close to the T-Mobile office in The Hague. We will exclude these tests as potentially being from T-Mobile employees.

Also see the [precision of the coordinates](#) denotes the fact that we are unsure about the exact location.

So what do we do with these suspicious coordinates?

The “Unknown” location, which has coordinates (52.5 , 5.75) and is the default location from Ookla if the GPS cannot pick up the exact location during the test, we have 28572 speed tests with this coordinate alone. We will exclude tests performed at this coordinate from the general analysis. Nevertheless, we will analyse this set the same way we analyse individual cities, the result for this set can be found as the last city labeled “unknown”.

T-Mobile head office We removed 241 tests from coordinates “52.0666 , 4.3209” in The Hague. As they are close to the head-office of T-Mobile and indeed all tests from this location are done from a T-Mobile network.

The other locations (“51.9167-4.5”, “52.3667-4.9”, “52.35-4.9167”) have been explained above and there is no knowledge at this point that leads to exclusion, so these tests remain in the data set.

After removing 241 tests from coordinates “52.0666 , 4.3209” in The Hague and 28572 from the coordinates (“52.5-5.75”) the data set contains $184356 - 28813 = 155543$ speed tests at this point.

4.6.2 Mapping test coordinates to city boundaries

To identify the exact 4G coverage area we will use in this analysis, we use data from CBS. CBS is the Central Bureau of Statistics in the Netherlands. They provide [publicly available](#) polygon data on cities in the Netherlands. Based on these geographical city boundaries we map each latitude, longitude coordinate onto a city.

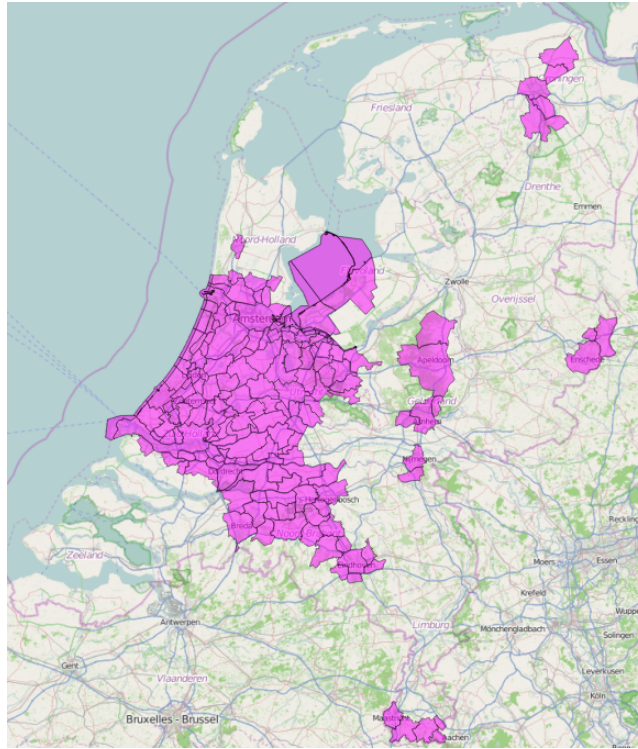
From T-Mobile we received a list of cities that, at the time of testing, have 4G coverage. From the data we can see that per city each provider has sufficient number of speed tests in the data set for the tests to be representative.

We use city boundaries to not be influenced by exact locations of network infrastructure.

Online we can get an up to date overview of network coverage for all three operators (see [here](#)).

This test is not about coverage but about speed of the 4G network.

T-Mobile has the least 4G coverage of the three operators and per end of 2014 has actual coverage in the following area:



In order to do a fair comparison, we focus only on the area presented in the picture above.

We do a Geo-spatial filter on the latitude and longitude coordinates provided in the data set and only keep speed tests that are in any of the above city boundaries. For the area, defined above, the following number of tests are available in the data set.

	Number of tests	percentage
KPN NL	30367	24.25
T-Mobile NL	55329	44.19
Vodafone NL	39505	31.55
Sum	125201	100.00

Table 6: Number of 4G speedtests in the selected coverage area.

Areas where T-Mobile announced 4G coverage in November 2014: Apeldoorn, Voorst, Dinkelland, Enschede, Losser, Oldenzaal. In December 2014 T-Mobile announced 4G coverage in : Eijsden, Maastricht, Margraten, Bedum, Groningen, Haren, Hoogezand-sappemeer, Leek, Loppersum, Noordenveld, Slochteren, Ten Boer, Tynaarlo.

Naturally, in these cities, almost all of T-Mobile's 4G speedtests occur after announcing to customers that 4G is activated, so November or December respectively, even though a very small number of tests were executed during the extension of the 4G coverage onto these cities, as 4G sites were being added (so before announcing 4G coverage in these cities; this is possible as for most 4G capable phones, the 4G network is selected automatically if available). In the same cities, KPN and Vodafone speedtests are distributed more evenly over the entire period of Q4/2014. However, this has no influence on the test results, as the test results per month do not differ substantially (please see section 4.6.4).

So we filtered the data set to include only speed tests from the coverage area, speed tests outside this area are neglected. The data set now contains $155543 - 30342 = 125201$ speed tests.

4.6.3 Suspicious speeds

In the data we check for up and download speeds that are technically impossible. *Download speeds* for 4G are limited to 150Mbps on the T-mobile technology.

KPN and Vodafone have a technology called LTE advanced which has a maximum download speed of 225Mbps.

Any speed tests that had a speed recorded above the technical maximum for that operator was removed from the data set.

So we remove suspicious measurements in which the **download** speed exceeded the maximum theoretical speed per individual operator.

For T-Mobile we removed 7 cases, for Vodafone we removed 3 cases and for KPN we removed 0 cases, because they were above 150(or 225) MBps.

After removing in total 10 of these suspicious measurements, the data set contains 125191 speed tests at this point.

Let's do the same for *upload speed*.

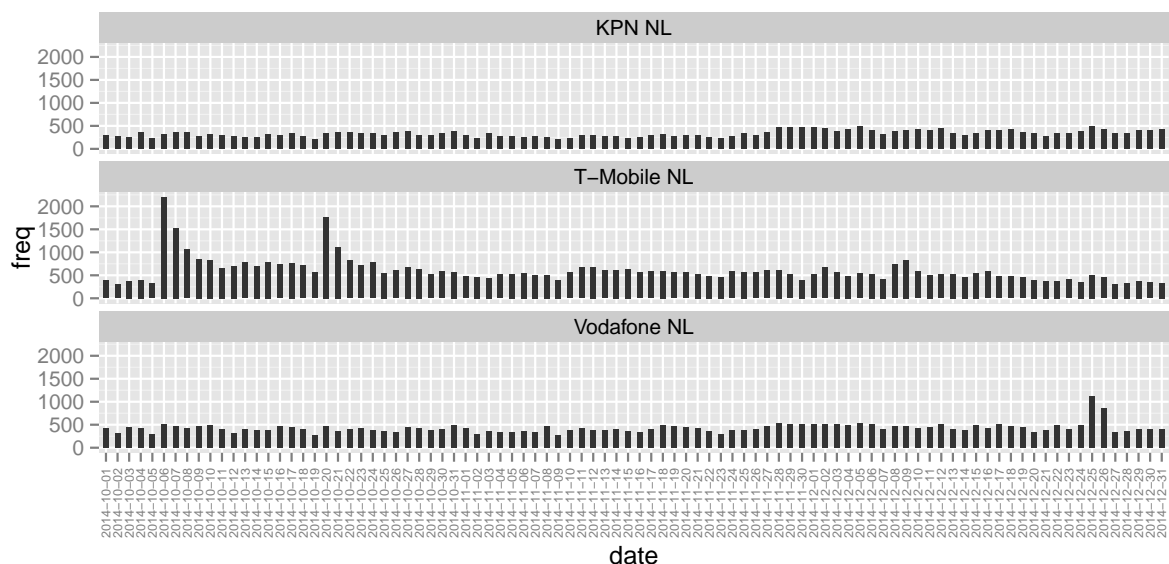
The maximum theoretical upload speed is for all operators the same: maximum upload speed of 50Mbps.

So again we remove suspicious measurements in which the **upload** speed exceeded the maximum theoretical speed per individual operator. For T-Mobile we removed 17 cases, for Vodafone we removed 14 cases and for KPN we removed 13 cases.

After removing in total 44 of these suspicious measurements the data set contains 125147 speed tests at this point.

4.6.4 Suspicious dates or times

We count the number of tests per day for the months October, November and December of 2014. Again we are looking at any suspicious peaks in the data?



We know that on 6 October T-Mobile introduced new improved speeds for all customers on the “Stel Samen” rate-plans. This led to an increased number of tests. Also Vodafone allowed 2 days of free data usages for Christmas (25/26th of December). We find no disturbing or unknown peaks on a specific date.

	december	november	oktober	Sum
KPN NL	12012	8812	9530	30354
T-Mobile NL	14957	16346	24002	55305
Vodafone NL	14882	11977	12629	39488
Sum	41851	37135	46161	125147

Table 7: Counts per operator per month

Above a count per month per operator in the 4G coverage area. This is the data set on which we conduct the remainder of the analysis.

In the tables below we list the averages for download speed, upload speed and latency per operator per month. Also, here we do not see fluctuations that are suspiciously high, so the testing frequencies per month are not a factor.

Operator	Month	Average Downloadspeed(Kbps)
KPN NL	december	23005.2
KPN NL	november	20978.5
KPN NL	oktober	22094.6
T-Mobile NL	december	37200.8
T-Mobile NL	november	37097.8
T-Mobile NL	oktober	36927.3
Vodafone NL	december	25286.8
Vodafone NL	november	23536.9
Vodafone NL	oktober	25003.4

Table 8: Average download speed(Kbps) per operator per month

Operator	Month	Average Uploadspeed(Kbps)
KPN NL	december	9621.4
KPN NL	november	9275.3
KPN NL	oktober	9677.1
T-Mobile NL	december	17248.5
T-Mobile NL	november	17594.6
T-Mobile NL	oktober	16939.3
Vodafone NL	december	14112.8
Vodafone NL	november	13245.7
Vodafone NL	oktober	13261.4

Table 9: Average upload speed(Kbps) per operator per month

Operator	Month	Average Latency(ms)
KPN NL	december	44.3
KPN NL	november	43.4
KPN NL	oktober	43.3
T-Mobile NL	december	38.5
T-Mobile NL	november	39.8
T-Mobile NL	oktober	38.6
Vodafone NL	december	48.5
Vodafone NL	november	48.5
Vodafone NL	oktober	46.8

Table 10: Average latency(ms) per operator per month

5 Step 3: Data analysis

So we have pre-processed the data and looked for anomalies in the data. If found, we have corrected them. Finally we are ready to compare speed test data between the three major telecom operators in Netherlands in the above defined coverage area.

We will analyse three different metrics:

- Download speed
- Upload speed
- Latency

There is no useful way to aggregate these individual metrics into one overall ‘speed aggregated score’. Most customers are interested in download speeds, because it affects the most of their experience (browsing, streaming, downloading etc). Most network speed comparisons only focus on download speed. However, since upload speed is also important for posting video’s and photos on social media, and ping times are important for gaming and fast opening of websites these metrics are also analyzed.

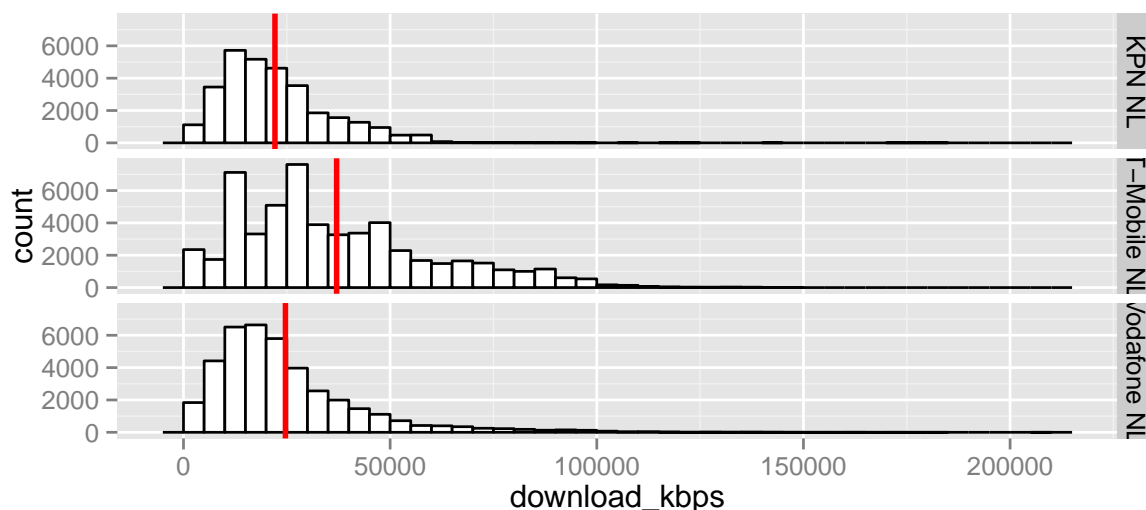
So how are the different metrics distributed?

5.1 Histogram distributions

A histogram is a graphical representation of the distribution of data. It is an estimate of the probability distribution of a continuous variable (quantitative variable), [more](#) about histograms on Wikipedia.

5.1.1 Download speed

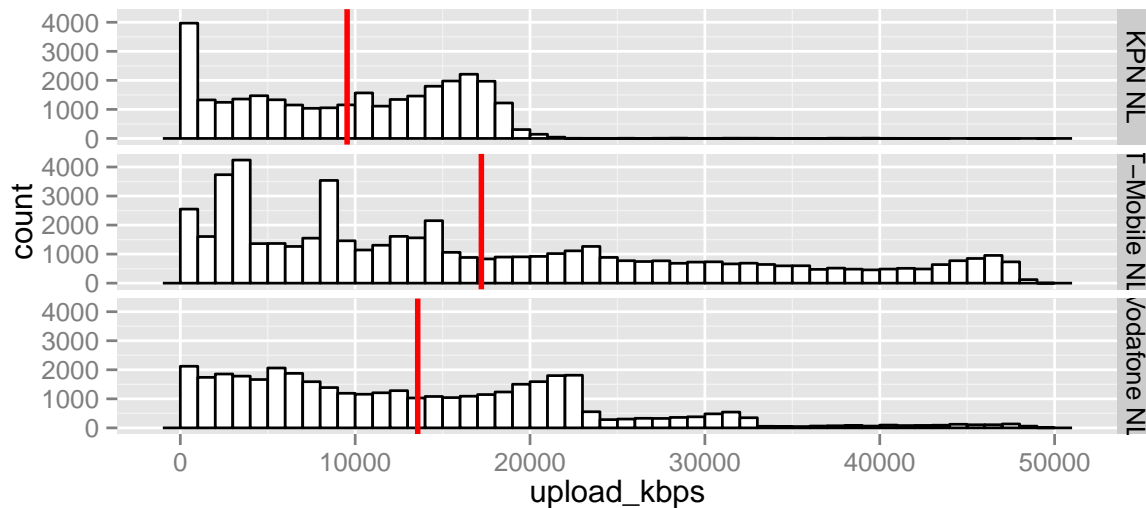
In the histogram below we see download speed in KBps on the horizontal axis. The number of test cases are plotted as bars, on the vertical axis we see the count of the number of speed tests in a specific bin (or range). The histogram gives a visual representation of the distribution of the data.



We plot the three histograms, one for each operator, right above each other so the horizontal axes are aligned. The red lines denotes the mean (or average) speed of all speed tests for the specific operator. If the red line is placed to the righthandside in this histogram that means the average speed for this operator is faster. The red line to the left means the avarage speed is slower. We can see that the red line of T-Mobile is farthest to the right so T-Mobile apparently has the highest average download speed.

5.1.2 Upload speed

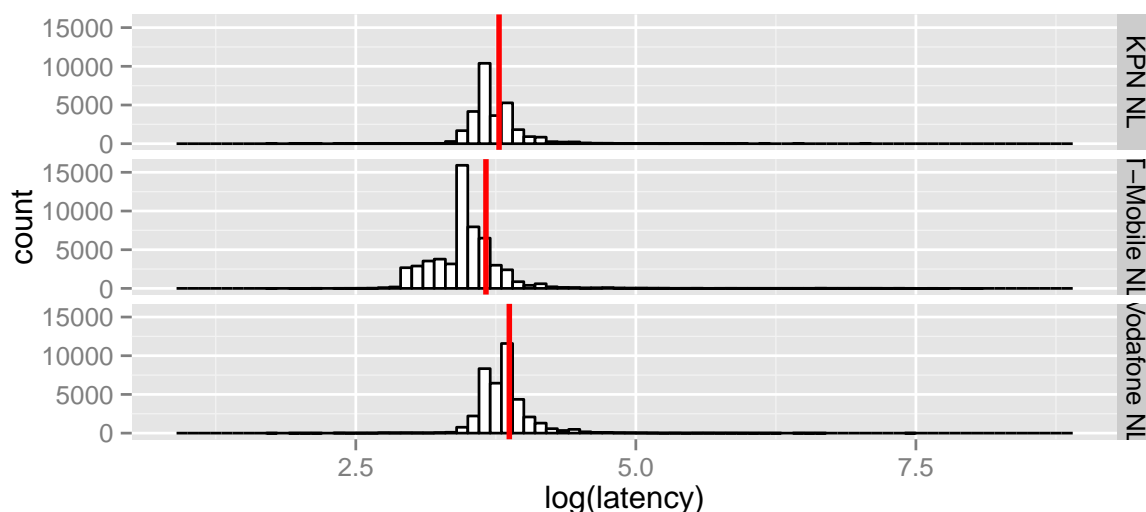
In the histogram below we see upload speed in KBps on the horizontal axis. The number of test cases are plotted as bars, on the vertical axis we see the count of the number of speed tests in a specific bin (or range). The histogram gives a visual representation of the distribution of the data.



We plot the three histograms, one for each operator, right above each other so the horizontal axes are aligned. The red lines denotes the mean (or average) speed of all speed tests for the specific operator. If the red line is placed to the righthandside in this histogram that means the average speed for this operator is faster. The red line to the left means the average speed is slower. We can see that the red line of T-Mobile is farthest to the right so T-Mobile apparently has the highest average upload speed as well.

5.1.3 Latency

In the histogram below we see $\log(\text{latency})$ speed on the horizontal axis. The log transformation makes the figure more readable. For the reader, the horizontal axis shows powers of 10. So 2 actually means $10^2 = 100$ and 5 actually stands for $10^5 = 10,000$. The number of test cases are plotted as bars, on the vertical axis we see the count of the number of speed tests in a specific range. For latency we take the log so the outlines scale and we can have a look at the shape of the distribution.



For latency smaller is better, so in this plot we are looking at which operator has the smallest latency. Again we see the red lines per operator. The x axis are on a log scale to these are factors of ten. The

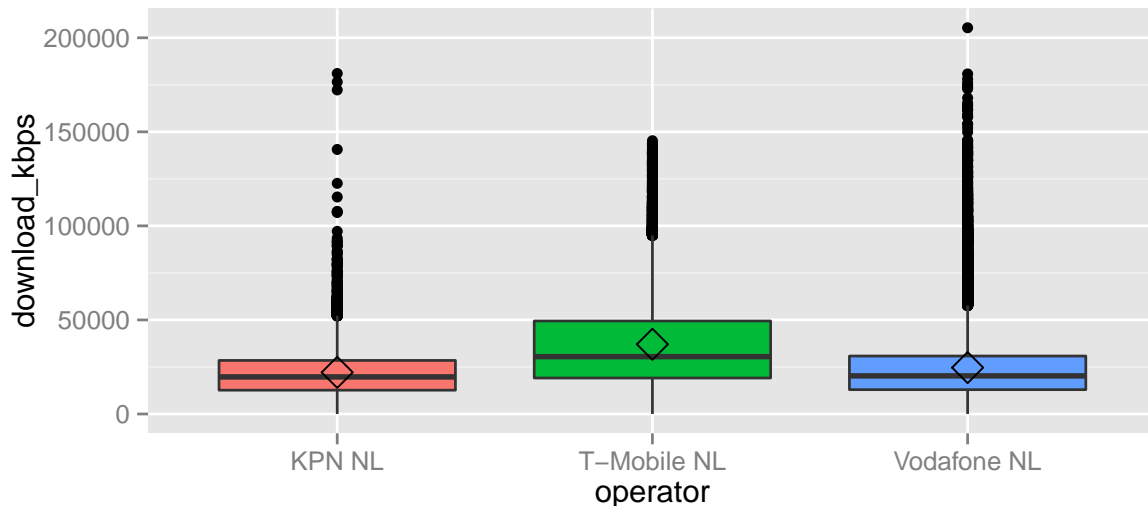
average latency(red line) for T-Mobile is the most to the left, which means T-Mobile has the smallest average latency of the three operators.

5.2 Box-plot

In descriptive statistics, a box plot or box-plot is a convenient way of graphically depicting groups of numerical data through their quartiles. Box plots may also have lines extending vertically from the boxes (whiskers) indicating variability outside the upper and lower quartiles, hence the terms box-and-whisker plot and box-and-whisker diagram. Outliers may be plotted as individual points. [More](#) about box-plots on Wikipedia.

5.2.1 Download speed

We see a box plot for each of the operators on the x axis, the vertical axis shows the speed test values in Kbps. The diamond shape represents the mean, the thick line represents the median. the black dots on the top and bottom represent extreme cases. The data is split up into quartiles, that means four equally sized proportions. The first and fourth quarter are represented as a line, the second and third as a box.



Also in the box-plot we see that for T-Mobile the diamond shape(average) and the thick line representing the median are higher then the same values for the other operators. So also in this box-plot for download speed we see that T-Mobile has the highest average and median download speed.

If we zoom in on percentiles we can look at the fastest 10%, 5% and 1% of speed tests:

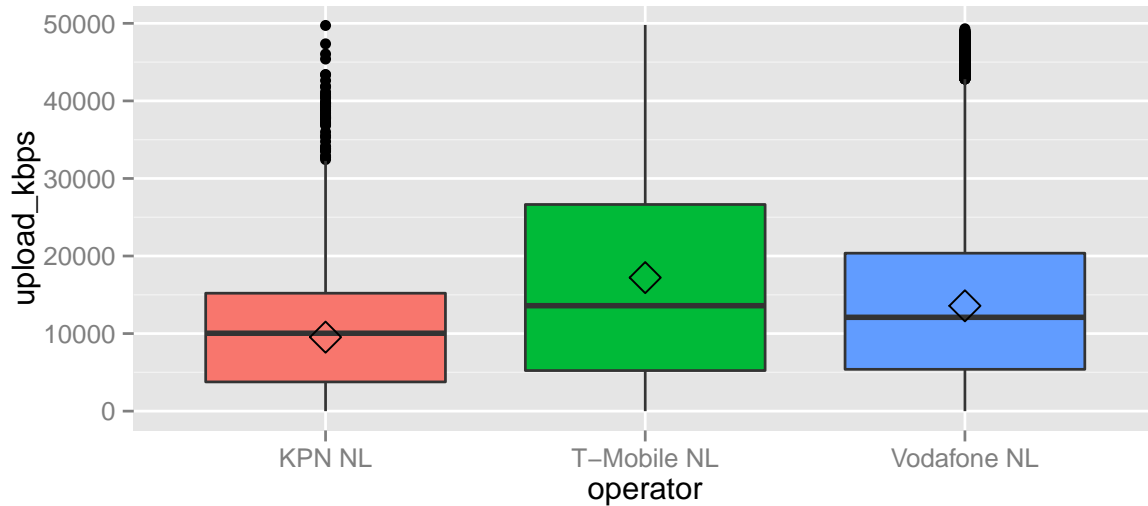
operator	10%	5%	1%
KPN NL	40978	47398	58495
T-Mobile NL	72628	85251	99873
Vodafone NL	46568	60826	94351

Table 11: Top percentiles average download speed(Kbps)

From the table we see that T-Mobile scores best in the fastest 10%,5% and 1% of download speed tests per operator.

5.2.2 Upload speed

We see a box plot for each of the operators on the x axis, the vertical axis shows the speed test values in Kbps. The diamond shape represents the mean, the thick line represents the median. the black dots on the top and bottom represent extreme cases. The data is split up into quartiles, that means four equally sized proportions. The first and fourth quarter are represented as a line, the second and third as a box.



Also in the box-plot we see that for T-Mobile the diamond shape(average) and the thick line representing the median are higher then the same values for the other operators. So also in this box-plot for upload speed we see that T-Mobile has the highest average and median upload speed.

If we zoom in on percentiles we can look at the fastest 10%, 5% and 1% of speed tests:

operator	10%	5%	1%
KPN NL	17364	18193	19949
T-Mobile NL	40052	44852	47305
Vodafone NL	26400	31482	45273

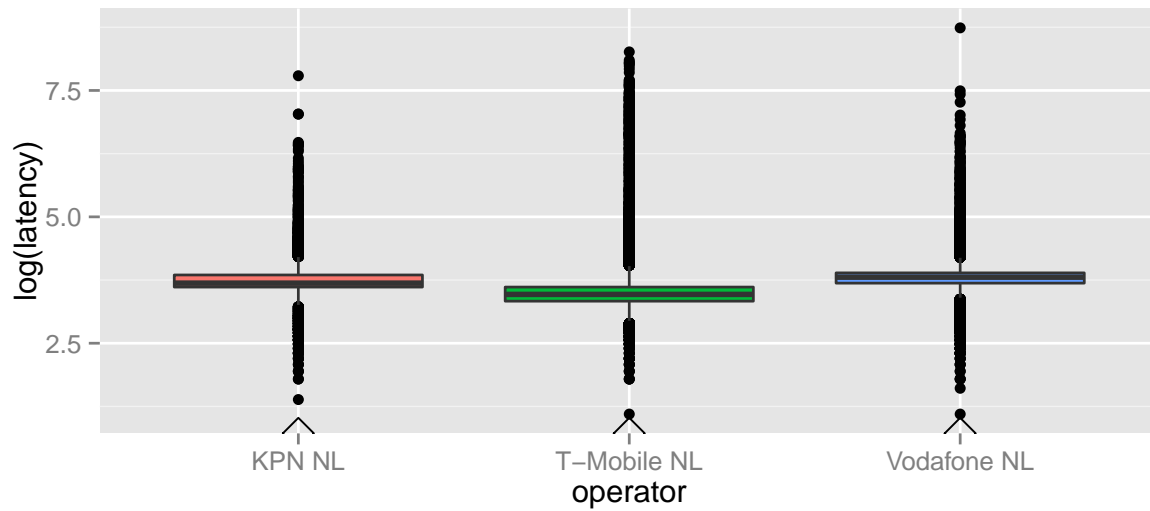
Table 12: Top percentiles average upload speed(Kbps)

From the table we see that T-Mobile scores best in the fastest 10%,5% and 1% of upload speed tests per operator.

5.2.3 Latency

For latency (or ping) we take the log so the outliers scale and we can have a look at the shape of the distribution.

We see a box plot for each of the operators on the x axis, the vertical axis shows the speed test values in Kbps. The diamond shape represents the mean, the thick line represents the median. the black dots on the top and bottom represent extreme cases. The data is split up into quartiles, that means four equally sized proportions. The first and fourth quarter are represented as a line, the second and third as a box.



In the box-plot for latency we see that for T-Mobile the diamond shape(average) and the thick line representing the median are lower then the same values for the other operators. remember, for latency lower is better. So in this box-plot for latency we see that T-Mobile has the lowest latency.

6 Step 4: Test design

What we want to test is if, on average, a customer that uses T-Mobile 4G Mobile Network gets a higher average speed (in terms of download speed, upload speed and latency) than a customer using KPN's or Vodafone's 4G Mobile Network, with all else equal. To do this we have collected thousands of Ookla NetMetrics Speedtest results taken from the three top operators (KPN, Vodafone and T-Mobile) which have been filtered as set out in the above to a final dataset consisting of 125147 data points. Now we want to compare T-Mobile with the other two operators. So we do two tests: the first is comparing T-Mobile with KPN and the second is comparing T-Mobile with Vodafone. In each test we compare all three metrics: Upload speed, Download speed and latency (or ping). For each operator we have a sample set available in the data. These sets are so called samples (from the Dutch population of mobile phone users) from which we calculate the sample means. Now our statistical test tests if these sample means are significantly different from one another.

In practice, the Central Limit Theorem assures us that, under a wide range of assumptions, the distributions of the two sample means being tested will themselves approach Normal distributions as the sample sizes get large, regardless (this is where the assumptions come in) of the distributions of the underlying data. As a consequence, as the sample size gets larger, the difference of the means becomes normally distributed, and the requirements necessary for the t-statistic of an unpaired t-test to have the nominal t distribution become satisfied.

6.1 Which statistical test do we need?

What we have here is a set of unpaired, independent, different sample size, different variance data. A suitable and powerful test for this kind of data is a [Welch t-test](#).

In statistics, Welch's t-test (or Welch-Aspin Test) is a two-sample location test, and is used to check the hypothesis that two populations have equal means (our NULL hypothesis). Welch's t-test is an adaptation of Student's t-test, and is intended for use when the two samples have possibly unequal variances (which is the case here). These tests are often referred to as "unpaired" or "independent samples" t-tests, as they are typically applied when the statistical units underlying the two samples being compared are non-overlapping (in our case the units are different people performing the test with different devices on different networks).

6.1.1 Significance

So when is a test significant? And if so at what level? And furthermore can we qualify such a significant result as good or bad? To start with the last remark, all qualifications of a statistical result are subjective. One way of looking at 95% confidence is that 1 out of 20 trials (in 5% of the cases) you make a so called Type 1 error, in which you wrongly reject the null-hypothesis. So in this case, if the p-value would be 0.05 (confidence level 95%) you would claim that operator x is faster than operator y while in fact they were not. In applied practice, confidence intervals are typically stated at the 95% or 99% confidence level (More on [significance](#)).

In our test we will set the confidence level to be 99%, which is more strict than 95%. This means we will reject the Null Hypothesis only if we are 99 % confident we do not make a mistake. From the test result we see that in most cases the calculated p-values are very much smaller than $1 - 0.99 = 0.01$, so changes of making this type of error are even considerably smaller than the claimed confidence level of 99%.

6.1.2 P-value

In statistics, the p-value is a function of the observed sample results (a statistic) that is used for testing a statistical hypothesis. Before performing the test a threshold value is chosen, called the significance level of the test, traditionally 5% or 1% and denoted as α . If the p-value is equal or smaller than the significance level (α), it suggests that the observed data is inconsistent with the assumption that the null hypothesis is true, and thus that hypothesis must be rejected and the alternative hypothesis is accepted as true (see [wikipedia](#)).

6.1.3 Confidence intervals

Confidence intervals consist of a range of values (interval) that act as good estimates of the unknown population parameter. The level of confidence of the confidence interval would indicate the probability that the confidence range captures this true population parameter given a distribution of samples. This value is represented by a percentage, so when we say, “we are 99% confident that the true value of the parameter is in our confidence interval”, we express that 99% of the observed confidence intervals will hold the true value of the parameter. A confidence interval does **not** predict that the true value of the parameter has a particular probability of being in the confidence interval given the data actually obtained. (see [wikipedia](#)).

7 Step 5: Test results coverage area

We test T-Mobile against the other two operators so we have two tests. We put the confidence level to 99 %. Our null-hypothesis is that the means are drawn from the same sample, so they are not different.

In this test we use the whole data set, in the next chapter we test each individual city.

Let see what our test results are:

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	55305	37052	30354	22131	< 2.22e-16	Yes	14920.7	+/- 323.4	67.4
T-Mobile	Vodafone	55305	37052	39488	24665	< 2.22e-16	Yes	12386.2	+/- 353.1	50.2

Table 13: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	55305	17217	30354	9538	< 2.22e-16	Yes	7678.2	+/- 177.5	80.5
T-Mobile	Vodafone	55305	17217	39488	13578	< 2.22e-16	Yes	3639.1	+/- 198.8	26.8

Table 14: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	55305	39	30354	44	< 2.22e-16	Yes	-4.8	+/- 0.9	-11
T-Mobile	Vodafone	55305	39	39488	48	< 2.22e-16	Yes	-9	+/- 1	-18.8

Table 15: Comparison of means for metric: latency(ms)

Explanation of terms

****Sample 1**:** Number of speed test samples for operator 1.

Sample 2: Number of speed test samples for operator 2.

Mean 1: Average speed of speed tests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speed tests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). 'Yes' means the test is significant, 'No' means the test is not significant.“))

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the mean divided by the slower of the two operators average speed.

Looking at the tables above we see that all results are significant at $\alpha = 0.01$ level(99% confidence level) and the resulting p-values are very small. This means we can reject the null-hypothesis with great confidence. Hence we can state that with 99% confidence the true difference in the means lies within the confidence interval provided in the table.

8 Conclusion

This analysis has been conducted with the utmost care and to the best knowledge of the analyst (DIKW Consulting). The analysis is opensource and all code can be downloaded, reviewed and repeated from [GitHub](#).

Overall we can say that based on the speedtest data analysed in the investigated area the 4G network of T-Mobile outperforms both KPN and Vodafone on download speed, upload speed and latency.

From the data analysed in the investigated area the average download speed of the 4G network of T-Mobile outperforms KPN by 14.92 Mbps, which is 67.4%. Also, from the data analysed in the investigated area the average download speed of the 4G network of T-Mobile outperforms Vodafone by 12.39 Mbps, which is 50.2%. From table 14 above similar statements can be derived for upload speed. For deriving these statements for latency, please see table 15 keeping in mind that smaller values are better.

For conclusions per individual city we refer to the section below. Please keep in mind that the significance of a test per city does not influence the significance of a test over the whole 4G area. The significance of a test per city only shows if the 4G network speeds (download speed, upload speed and latency) are also significantly different on a local level, so for that city treated separately.

9 Analysis and results Top 20 cities per city

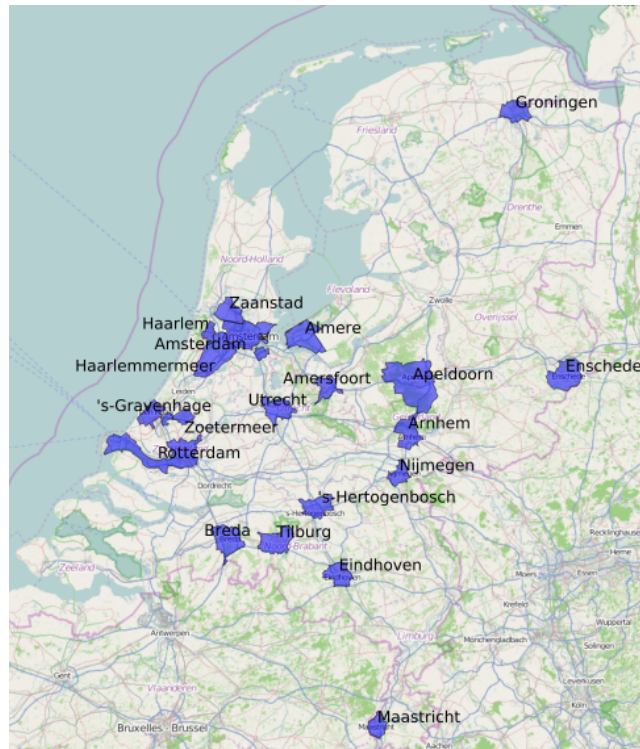
From CBS we have the following top 20 cities based on number of inhabitants(“aantal inwoners”).

gm_code	gm_naam	aantal_inwoners
GM0363	Amsterdam	799275
GM0599	Rotterdam	616295
GM0518	's-Gravenhage	505855
GM0344	Utrecht	321915
GM0772	Eindhoven	218430
GM0855	Tilburg	208525
GM0014	Groningen	195415
GM0034	Almere	195210
GM0758	Breda	178140
GM0268	Nijmegen	166380
GM0153	Enschede	158625
GM0200	Apeldoorn	157315
GM0392	Haarlem	153090
GM0202	Arnhem	149825
GM0307	Amersfoort	149660
GM0479	Zaanstad	149620
GM0394	Haarlemmermeer	144150
GM0796	's-Hertogenbosch	142815
GM0637	Zoetermeer	123090
GM0935	Maastricht	121820

In this test we use the CBS cities in this area as the benchmark area for the overall comparison.

In more detailed analysis we investigate the top twenty “Gemeentes” based on number of inhabitants. based on data available at [CBS](#).

The coverage area of top 20 cities looks like this.



From the CBS data we learn that the top 20 cities covers 4855450 out of 16779185 inhabitants. Which is 28.94 %. in terms of area this is 2412 km² of a total of 41545 km², which is 5.81%.

For each city we will do the significance test separately in the next pages.

Please note that T-Mobile commercially announced 4G coverage in November 2014 in Apeldoorn and Enschede and in December 2014 in Groningen and Maastricht. Naturally, in these cities, almost all of T-Mobile's 4G speedtests occur after announcing to customers that 4G is activated, so November or December respectively, even though a very small number of tests were executed during the extension of the 4G coverage onto these cities, as 4G sites were being added (so before announcing 4G coverage in these cities; this is possible as for most 4G capable phones, the 4G network is selected automatically if available). In the same cities, KPN and Vodafone speedtests are distributed more evenly over the entire period of Q4/2014. However, this has no influence on the test results, as the test results per month do not differ substantially (please see section 4.6.4).

9.1 Gemeente Amsterdam

The table shows the speed test analysis for gemeente Amsterdam. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	11944	38788	7008	22717	< 2.22e-16	Yes	16071.1	+/- 714	70.7
T-Mobile	Vodafone	11944	38788	10588	27194	< 2.22e-16	Yes	11594.6	+/- 778.7	42.6

Table 17: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	11944	17556	7008	9012	< 2.22e-16	Yes	8544.2	+/- 382.3	94.8
T-Mobile	Vodafone	11944	17556	10588	14764	< 2.22e-16	Yes	2792.2	+/- 426.7	18.9

Table 18: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	11944	38	7008	43	2.6189e-09	Yes	-5	+/- 2.2	-11.5
T-Mobile	Vodafone	11944	38	10588	46	< 2.22e-16	Yes	-7.8	+/- 2.2	-16.9

Table 19: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.2 Gemeente Rotterdam

The table shows the speed test analysis for gemeente Rotterdam. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	5329	34480	1560	21392	< 2.22e-16	Yes	13088.3	+/- 1085.6	61.2
T-Mobile	Vodafone	5329	34480	2319	32646	0.0014059	Yes	1834	+/- 1479	5.6

Table 20: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	5329	19069	1560	10273	< 2.22e-16	Yes	8795.8	+/- 632	85.6
T-Mobile	Vodafone	5329	19069	2319	15875	< 2.22e-16	Yes	3194	+/- 788.4	20.1

Table 21: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	5329	39	1560	41	0.031362	No	-2.5	+/- 3	NA
T-Mobile	Vodafone	5329	39	2319	48	6.0249e-16	Yes	-9.4	+/- 3	-19.6

Table 22: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1****: Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.3 Gemeente 's-Gravenhage

The table shows the speed test analysis for gemeente 's-Gravenhage. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	4419	38610	1678	20450	< 2.22e-16	Yes	18160	+/- 1256.7	88.8
T-Mobile	Vodafone	4419	38610	1801	27763	< 2.22e-16	Yes	10846.9	+/- 1583.2	39.1

Table 23: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	4419	20503	1678	9678	< 2.22e-16	Yes	10824.2	+/- 690.7	111.8
T-Mobile	Vodafone	4419	20503	1801	13684	< 2.22e-16	Yes	6818.3	+/- 875	49.8

Table 24: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	4419	36	1678	43	2.5919e-10	Yes	-7.1	+/- 2.9	-16.6
T-Mobile	Vodafone	4419	36	1801	51	< 2.22e-16	Yes	-15.5	+/- 3.8	-30.3

Table 25: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.4 Gemeente Utrecht

The table shows the speed test analysis for gemeente Utrecht. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	2104	33705	957	20138	< 2.22e-16	Yes	13566.4	+/- 1605.1	67.4
T-Mobile	Vodafone	2104	33705	1843	29199	3.9628e-11	Yes	4505.7	+/- 1752.9	15.4

Table 26: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	2104	17180	957	9386	< 2.22e-16	Yes	7794.5	+/- 918	83
T-Mobile	Vodafone	2104	17180	1843	14729	7.2296e-11	Yes	2451	+/- 966.7	16.6

Table 27: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	2104	41	957	47	0.00032919	Yes	-6.8	+/- 4.9	-14.3
T-Mobile	Vodafone	2104	41	1843	47	0.0009359	Yes	-6	+/- 4.7	-12.9

Table 28: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.5 Gemeente Eindhoven

The table shows the speed test analysis for gemeente Eindhoven. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	1630	32354	773	22819	< 2.22e-16	Yes	9535	+/- 1784	41.8
T-Mobile	Vodafone	1630	32354	1239	23483	< 2.22e-16	Yes	8870.6	+/- 1849.1	37.8

Table 29: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	1630	16430	773	10613	< 2.22e-16	Yes	5817.1	+/- 1016	54.8
T-Mobile	Vodafone	1630	16430	1239	13954	1.0832e-09	Yes	2476.6	+/- 1043.5	17.7

Table 30: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	1630	42	773	45	0.075753	No	-3.2	+/- 4.7	NA
T-Mobile	Vodafone	1630	42	1239	48	0.001218	Yes	-5.9	+/- 4.7	-12.2

Table 31: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1****: Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.6 Gemeente Tilburg

The table shows the speed test analysis for gemeente Tilburg. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	714	37174	397	21674	< 2.22e-16	Yes	15499.6	+/- 2684.5	71.5
T-Mobile	Vodafone	714	37174	484	17022	< 2.22e-16	Yes	20151.3	+/- 2519.9	118.4

Table 32: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	714	16142	397	10294	< 2.22e-16	Yes	5848.7	+/- 1440.2	56.8
T-Mobile	Vodafone	714	16142	484	11015	< 2.22e-16	Yes	5127.5	+/- 1516.8	46.6

Table 33: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	714	40	397	47	0.13088	No	-6.6	+/- 11.3	NA
T-Mobile	Vodafone	714	40	484	51	0.014427	No	-10.7	+/- 11.3	NA

Table 34: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.7 Gemeente Groningen

The table shows the speed test analysis for gemeente Groningen. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	776	37922	797	21228	< 2.22e-16	Yes	16694	+/- 2494.2	78.6
T-Mobile	Vodafone	776	37922	1011	19617	< 2.22e-16	Yes	18305.8	+/- 2428.4	93.3

Table 35: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	776	15554	797	8729	< 2.22e-16	Yes	6824.7	+/- 1373.9	78.2
T-Mobile	Vodafone	776	15554	1011	11592	1.2431e-12	Yes	3962.3	+/- 1424.1	34.2

Table 36: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	776	39	797	43	1.0996e-08	Yes	-3.3	+/- 1.5	-7.7
T-Mobile	Vodafone	776	39	1011	53	< 2.22e-16	Yes	-13.5	+/- 2.3	-25.6

Table 37: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.8 Gemeente Almere

The table shows the speed test analysis for gemeente Almere. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	959	39107	541	19245	< 2.22e-16	Yes	19861.4	+/- 2420.1	103.2
T-Mobile	Vodafone	959	39107	546	20074	< 2.22e-16	Yes	19032.4	+/- 2573.5	94.8

Table 38: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	959	16141	541	8394	< 2.22e-16	Yes	7746.8	+/- 1330.3	92.3
T-Mobile	Vodafone	959	16141	546	11031	< 2.22e-16	Yes	5110.1	+/- 1453.7	46.3

Table 39: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	959	34	541	43	< 2.22e-16	Yes	-8.2	+/- 2.4	-19.2
T-Mobile	Vodafone	959	34	546	47	< 2.22e-16	Yes	-12.2	+/- 2.3	-26.2

Table 40: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1****: Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.9 Gemeente Breda

The table shows the speed test analysis for gemeente Breda. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	919	36514	479	23097	< 2.22e-16	Yes	13416.7	+/- 2574.3	58.1
T-Mobile	Vodafone	919	36514	430	19720	< 2.22e-16	Yes	16793.5	+/- 2402.4	85.2

Table 41: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	919	17753	479	9639	< 2.22e-16	Yes	8114	+/- 1458.8	84.2
T-Mobile	Vodafone	919	17753	430	12356	< 2.22e-16	Yes	5396.9	+/- 1651.1	43.7

Table 42: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	919	42	479	45	0.28234	No	-3.4	+/- 8.1	NA
T-Mobile	Vodafone	919	42	430	48	0.049178	No	-6.2	+/- 8.2	NA

Table 43: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1****: Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.10 Gemeente Nijmegen

The table shows the speed test analysis for gemeente Nijmegen. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	744	34036	495	20061	< 2.22e-16	Yes	13974.5	+/- 2582.3	69.7
T-Mobile	Vodafone	744	34036	606	19795	< 2.22e-16	Yes	14241	+/- 2428.3	71.9

Table 44: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	744	15481	495	10184	< 2.22e-16	Yes	5297	+/- 1413.7	52
T-Mobile	Vodafone	744	15481	606	13398	0.00038553	Yes	2082.1	+/- 1509	15.5

Table 45: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	744	40	495	43	0.36903	No	-2.9	+/- 8.3	NA
T-Mobile	Vodafone	744	40	606	46	0.043233	No	-6.5	+/- 8.3	NA

Table 46: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1****: Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.11 Gemeente Enschede

The table shows the speed test analysis for gemeente Enschede. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	719	28300	466	23147	3.8143e-09	Yes	5152.2	+/- 2239	22.3
T-Mobile	Vodafone	719	28300	484	20974	< 2.22e-16	Yes	7325.3	+/- 2213	34.9

Table 47: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	719	13980	466	10108	3.6365e-12	Yes	3872	+/- 1421.1	38.3
T-Mobile	Vodafone	719	13980	484	12831	0.07509	No	1148.8	+/- 1663.7	NA

Table 48: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	719	34	466	43	< 2.22e-16	Yes	-8.8	+/- 1.7	-20.4
T-Mobile	Vodafone	719	34	484	52	< 2.22e-16	Yes	-17.9	+/- 2	-34.3

Table 49: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1****: Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.12 Gemeente Apeldoorn

The table shows the speed test analysis for gemeente Apeldoorn. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	780	34169	606	22552	< 2.22e-16	Yes	11616.9	+/- 2498.1	51.5
T-Mobile	Vodafone	780	34169	525	19416	< 2.22e-16	Yes	14753.4	+/- 2429.4	76

Table 50: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	780	14337	606	9077	< 2.22e-16	Yes	5260.3	+/- 1392.2	58
T-Mobile	Vodafone	780	14337	525	10804	1.3591e-08	Yes	3533.5	+/- 1595	32.7

Table 51: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	780	38	606	50	1.2341e-05	Yes	-11.6	+/- 6.8	-23.4
T-Mobile	Vodafone	780	38	525	56	3.3462e-11	Yes	-17.6	+/- 6.8	-31.7

Table 52: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.13 Gemeente Haarlem

The table shows the speed test analysis for gemeente Haarlem. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	1001	39332	319	20693	< 2.22e-16	Yes	18639.6	+/- 2622.7	90.1
T-Mobile	Vodafone	1001	39332	516	19460	< 2.22e-16	Yes	19872	+/- 2654	102.1

Table 53: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	1001	18702	319	9247	< 2.22e-16	Yes	9455.2	+/- 1444.1	102.3
T-Mobile	Vodafone	1001	18702	516	11560	< 2.22e-16	Yes	7141.9	+/- 1506.6	61.8

Table 54: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	1001	36	319	48	1.3231e-09	Yes	-11.3	+/- 4.8	-23.7
T-Mobile	Vodafone	1001	36	516	44	2.6713e-07	Yes	-7.2	+/- 3.6	-16.6

Table 55: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.14 Gemeente Arnhem

The table shows the speed test analysis for gemeente Arnhem. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	1232	35377	535	22162	< 2.22e-16	Yes	13214.6	+/- 2211.3	59.6
T-Mobile	Vodafone	1232	35377	600	20018	< 2.22e-16	Yes	15359	+/- 2428.9	76.7

Table 56: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	1232	14966	535	10097	< 2.22e-16	Yes	4868.7	+/- 1158.6	48.2
T-Mobile	Vodafone	1232	14966	600	11426	2.6849e-12	Yes	3539.6	+/- 1295.5	31

Table 57: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	1232	35	535	45	4.9058e-14	Yes	-9.3	+/- 3.2	-20.9
T-Mobile	Vodafone	1232	35	600	46	6.9647e-12	Yes	-10.5	+/- 3.9	-23

Table 58: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.15 Gemeente Amersfoort

The table shows the speed test analysis for gemeente Amersfoort. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	589	31892	478	21967	< 2.22e-16	Yes	9924.7	+/- 2475.3	45.2
T-Mobile	Vodafone	589	31892	564	19276	< 2.22e-16	Yes	12615.8	+/- 2309.1	65.4

Table 59: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	589	14200	478	9620	< 2.22e-16	Yes	4579.9	+/- 1386.8	47.6
T-Mobile	Vodafone	589	14200	564	12887	0.026347	No	1313.3	+/- 1523.7	NA

Table 60: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	589	47	478	43	0.43137	No	4	+/- 13	NA
T-Mobile	Vodafone	589	47	564	48	0.85963	No	-0.9	+/- 13.2	NA

Table 61: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.16 Gemeente Zaanstad

The table shows the speed test analysis for gemeente Zaanstad. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	679	39189	286	22705	< 2.22e-16	Yes	16484.1	+/- 3093.1	72.6
T-Mobile	Vodafone	679	39189	451	20472	< 2.22e-16	Yes	18716.7	+/- 2797.6	91.4

Table 62: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	679	16541	286	9699	< 2.22e-16	Yes	6841.8	+/- 1643.6	70.5
T-Mobile	Vodafone	679	16541	451	14573	0.0034842	Yes	1968	+/- 1734.5	13.5

Table 63: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	679	39	286	39	0.98802	No	0	+/- 8.1	NA
T-Mobile	Vodafone	679	39	451	42	0.46111	No	-2.3	+/- 8	NA

Table 64: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.17 Gemeente Haarlemmermeer

The table shows the speed test analysis for gemeente Haarlemmermeer. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	1253	38362	645	20414	< 2.22e-16	Yes	17947.7	+/- 2089.7	87.9
T-Mobile	Vodafone	1253	38362	904	26291	< 2.22e-16	Yes	12071	+/- 2417.1	45.9

Table 65: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	1253	17862	645	9314	< 2.22e-16	Yes	8548.1	+/- 1227	91.8
T-Mobile	Vodafone	1253	17862	904	14536	1.2382e-10	Yes	3325.4	+/- 1325.8	22.9

Table 66: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	1253	38	645	41	0.15618	No	-2.9	+/- 5.3	NA
T-Mobile	Vodafone	1253	38	904	47	4.3355e-05	Yes	-8.6	+/- 5.4	-18.5

Table 67: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.18 Gemeente 's-Hertogenbosch

The table shows the speed test analysis for gemeente 's-Hertogenbosch. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	523	34309	492	23716	< 2.22e-16	Yes	10593.1	+/- 3222.1	44.7
T-Mobile	Vodafone	523	34309	586	22387	< 2.22e-16	Yes	11921.9	+/- 3169.4	53.3

Table 68: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	523	14604	492	11412	2.0867e-07	Yes	3192.2	+/- 1572.9	28
T-Mobile	Vodafone	523	14604	586	12204	0.00029812	Yes	2399.9	+/- 1706.1	19.7

Table 69: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	523	44	492	50	0.0001176	Yes	-6	+/- 4	-12.1
T-Mobile	Vodafone	523	44	586	49	0.0014804	Yes	-5	+/- 4	-10.3

Table 70: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.19 Gemeente Zoetermeer

The table shows the speed test analysis for gemeente Zoetermeer. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	780	37846	340	20101	< 2.22e-16	Yes	17744.4	+/- 2702	88.3
T-Mobile	Vodafone	780	37846	349	20444	< 2.22e-16	Yes	17402.1	+/- 2678.6	85.1

Table 71: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	780	18835	340	9326	< 2.22e-16	Yes	9509.2	+/- 1556.7	102
T-Mobile	Vodafone	780	18835	349	13904	1.9058e-11	Yes	4930.6	+/- 1872.2	35.5

Table 72: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	780	33	340	43	< 2.22e-16	Yes	-9.9	+/- 2.9	-23.1
T-Mobile	Vodafone	780	33	349	48	< 2.22e-16	Yes	-15.1	+/- 2.9	-31.5

Table 73: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.20 Gemeente Maastricht

The table shows the speed test analysis for gemeente Maastricht. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	439	28964	224	23202	1.0663e-06	Yes	5762.2	+/- 3021.6	24.8
T-Mobile	Vodafone	439	28964	1050	27973	0.38049	No	990.6	+/- 2913.8	NA

Table 74: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	439	11603	224	10173	0.036675	No	1429.5	+/- 1763.9	NA
T-Mobile	Vodafone	439	11603	1050	15302	1.8097e-08	Yes	-3699.8	+/- 1678.8	-31.9

Table 75: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	439	65	224	56	0.0055696	Yes	9	+/- 8.4	13.9
T-Mobile	Vodafone	439	65	1050	59	0.3801	No	5.9	+/- 17.5	NA

Table 76: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.

9.21 Gemeente Unkown Location

The table shows the speed test analysis for gemeente Unkown Location. For this test the confidence level is set to 99%.

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	7974	33863	9135	20316	< 2.22e-16	Yes	13546.2	+/- 751.7	66.7
T-Mobile	Vodafone	7974	33863	11463	23038	< 2.22e-16	Yes	10825	+/- 784.8	47

Table 77: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	7974	15445	9135	8886	< 2.22e-16	Yes	6559.2	+/- 407.1	73.8
T-Mobile	Vodafone	7974	15445	11463	11682	< 2.22e-16	Yes	3763	+/- 428.6	32.2

Table 78: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	7974	42	9135	43	0.72258	No	-0.5	+/- 3.5	NA
T-Mobile	Vodafone	7974	42	11463	48	2.046e-05	Yes	-5.8	+/- 3.5	-12

Table 79: Comparison of means for metric: latency(ms)

Please note the column [Sign.] or “Significant”, if this column states “No” the test is not significant at the 99% confidence level. This means there is no significant difference in means observed so the NULL Hypothesis can not be rejected. In layman’s terms: You *cannot* conclude that one operator has a faster 4G network then the other on that particular 4G network speed measurement (download speed, upload speed or latency).

Explanation of terms

****Sample 1**:** Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

Mean 1: Average speed of speedtests for operator 1 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

Mean 2: Average speed of speedtests for operator 2 in KBps. A high number here means that this operator has a fast download(or upload) speed. For the latency a high number means you have to wait longer to contact webpages or servers.

P-value: The test statistic, for more explanation see the paragraph P-Value above

Sign.: Short for Significance. We compare the test statistic with the predefined confidence level(0.99). ‘Yes’ means the test is significant, ‘No’ means the test is not significant.”)

Diff(in Kbps or ms): Difference of the means (DoM) is the difference of Mean 1 and Mean 2(Mean 1 - Mean 2). For download and upload speeds(Kbps) big positive number here means operator 1 has a faster speed then operator 2. A big negative number means that operator 2 has a faster speed then operator 1. For latency(ms) this is the opposite, because smaller is better.

Conf Int: Confidence interval consist of a range of values (interval) that act as good estimate of the *true* difference of the mean. We are 99% confident that the true value of the difference of the mean is in our confidence interval.

Rel(%): Relative difference in percentage. It is calculated as the difference of the means divided by the slower of the two operators average speed.