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

Hugo Koopmans

17-04-2015

Contents

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 sftandards. 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 ot 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 January, February and March 2015. 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 Q1 2015 so the months January, February and March of 2015 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 Q1/2015.

	Counts
Android	156577
iOS	119648
Windows	6998
Sum	283223

Table 1: Raw test data counts

So we start this analysis with in total 283223 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 Speeedtest.net.

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 descriptives

```
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=Utms, 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=HSUPA, 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=EVDV, 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.

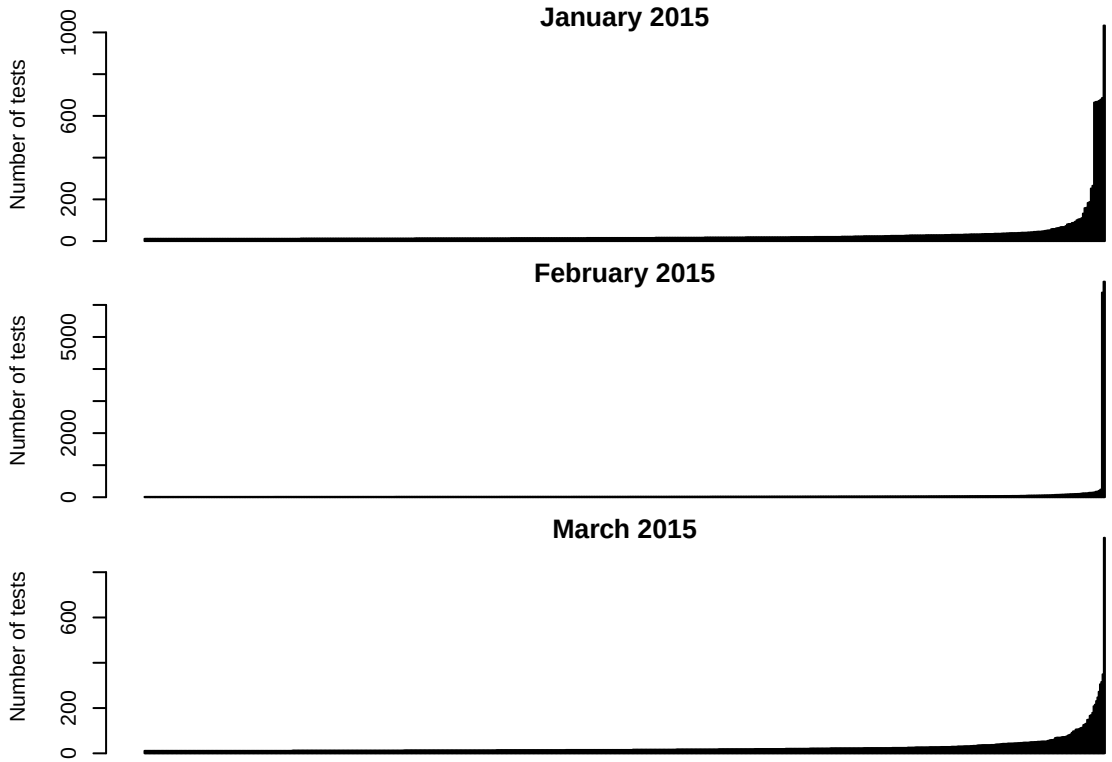
First of all, the names for the individual operators are spelled in various ways (e.g. 'T-Mobile NL', 'T-Mobile NL'). Next, we need to map connection types to the specific technology used (2G, 3G or 4G) depending on the operating system of the device. For more details on these transformations, please 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 97 devices in January, 99 devices in February and 115 devices in March, which in total represent 37574 speed tests. After filtering these devices the data set has 283223-37574=245649 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 806 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
KPN NL	73496
Vodafone NL	64982
T-Mobile NL	59127
Carrier	3838
Telfort NL	3329
TURKCELL	2774

Operator	Number of speedtests
TELE2	2470
DiGi	1834
Hi	1830
Tele2 NL	1758

Table 2: Most frequent operators

The top three operators together are good for 197605 tests conducted all over the Netherlands in the test period of Q1 2015. We keep only speed tests from the top three operators.

This leaves 245649 - 48044 = 197605 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	2501	1.27
3G	55002	27.83
4G	139557	70.62
UNKNOWN	69	0.03
WIFI/CELL	476	0.24

Table 3: Technology used in tests

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

Filtering on 4G technology leaves 139557 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	31528	26537	28732
iOS	40066	31542	34400
Windows	1902	1048	1850

Most of the tests were conducted on iOS closely followed by Android OS. 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 Q1 2015, the period of the test. All of the top 20 cities in the Netherlands, which we will analyze per city, had 4G enabled prior to Q1 2015.

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 a online service to estimate the physical location of an ip-internet address (more online from maxmind).

Coordinates	Count
52.3667 , 4.9	36692
52.35 , 4.9167	2436
51.9167 , 4.5	407
52.3666 , 4.9027	325
52.0833 , 4.3	252
51.8059 , 4.5634	179
52.0938 , 5.1191	179
52.3881 , 5.2354	140
51.8007 , 4.6982	139
51.8796 , 4.5059	113
52.3025 , 4.6889	89
52.0666 , 4.3209	65
52.1583 , 4.4931	64

Coordinates	Count
52.352 , 4.8875	64
51.4408 , 5.4778	60

There is a difference between Q4 2014 and Q1 2015. The coordinate (52.5-5.75) which was the default coordinate for the Netherlands in Q4 2014 and described as 'the Center of Kansas for The Netherlands' by Ookla in the Q4/2014 Paper is no longer present in the data set. Instead, the coordinate (52.3667, 4.9) is now the most frequent one. We assumed that this is the new default coordinate for the Netherlands, when the exact location is unknown. We asked for an explanation from Ookla on this change and questions on the other frequent and rounded coordinates.

Coordinate (52.3667,4.9 vs 52.5-5.75) : Response from Ookla: *Results are definitely coming from GEO-IP Coordinates as you know. 2. In a single day here, there is 191 results from the same IP block to this location. 3. Correct, this is similar to the 'Kansas' issue we discussed last year.*

Coordinate (52.35-4.9167) is in Amsterdam. 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 (52.3667 , 4.9) and is the default location from Ookla if the GPS cannot pick up the exact location during the test, we have 36692 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 65 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", "52.35-4.9167") 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 65 tests from coordinates "52.0666 , 4.3209" in The Hague and 36692 from the coordinates "52.0666 , 4.3209" the data set contains 139557 - 36757 = 102800 speed tests at this point.

4.6.2 Mapping test coordiantes 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.

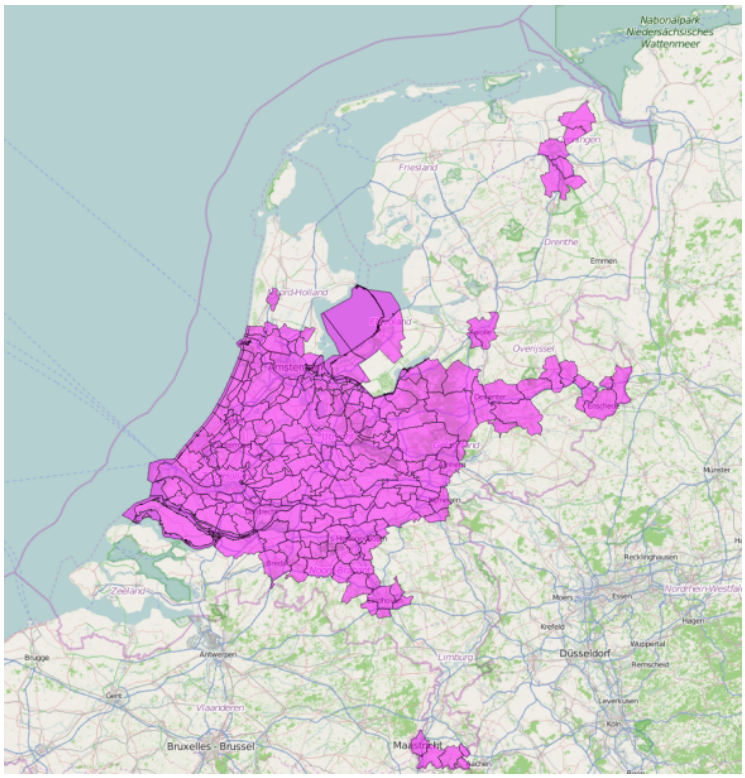
From T-Mobile we received a list of cities that, at the time of testing, have 4G coverage. From the data we can see that per city each provider has sufficient number of speed tests in the data set for the tests to be representative.

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 Q1 2015 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-spacial 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	26273	31.00
T-Mobile NL	31985	37.74
Vodafone NL	26492	31.26
Sum	84750	100.00

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

Areas where T-Mobile announced 4G coverage in Q1 2015: Buren, Culemborg, Geldermalsen, Scherpenzeel, Tiel, Neerijnen, Renswoude, Wijk bij Duurstede, Sint-Michielsgestel, Utrechtse Heuvelrug and Maasdonk, were added in January; Barneveld, Ede, Veenendaal, Hellevoetsluis, Bernisse, Korendijk, Cromstrijen, Westvoorne, Strijen, Moerdijk and Goeree-Overflakkee were added in February; Almelo, Borne, Deventer, Hengelo, Wierden, Zwolle, Beuningen, Druten, Ermelo, Harderwijk, Hattem, Lochem, Putten, Voorst, Wageningen, Wijchen, Zutphen, Nunspeet, Rhenen, West Maas en Waal, Oss, Overbetuwe, Neder-Betuwe and Rijssen-Holten were added in March.

Naturally, in these cities, almost all of T-Mobile's 4G speedtests occur after announcing to customers that 4G is activated, so January, February or March 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 Q1/2015. 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 102800 - 18050 = 84750 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 10 cases, for Vodafone we removed 0 cases and for KPN we removed 0 cases, because they where above 150(or 225) MBps.

After removing in total 10 of these suspicious measurements, the data set contains 84740 speed tests at this point.

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

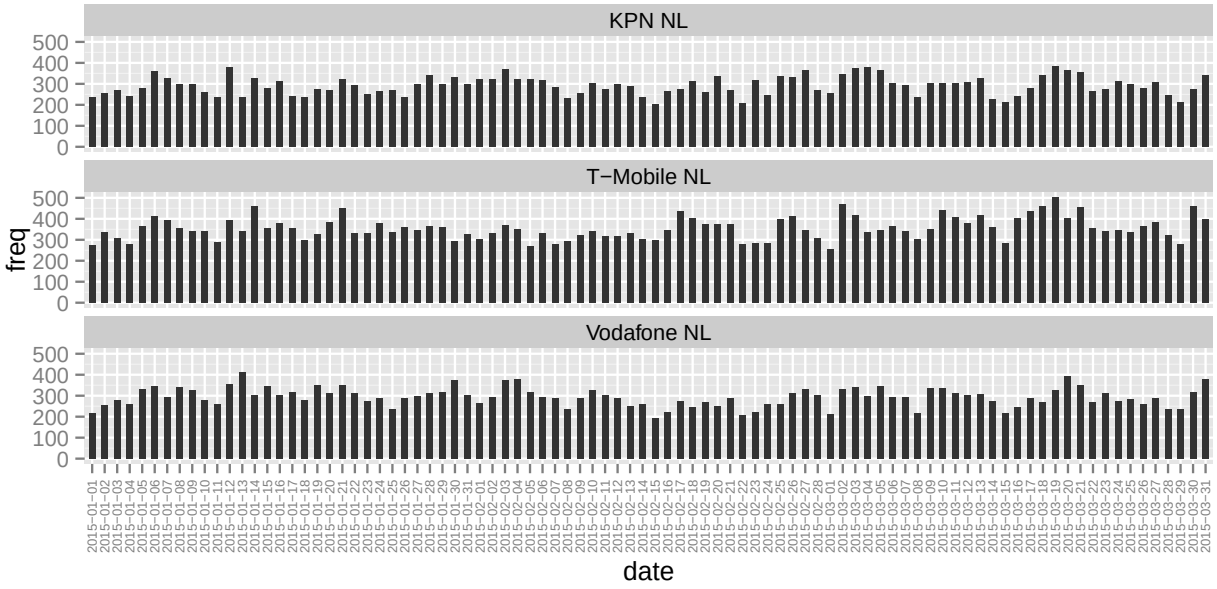
The maximum theoretical upload speed is for all operators the same: maximum upload speed of 50Mbps.

So again we remove suspicious measurements in which the **upload** speed exceeded the maximum theoretical speed per individual operator. For T-Mobile we removed 16 cases, for Vodafone we removed 18 cases and for KPN we removed 25 cases.

After removing in total 59 of these suspicious measurements the data set contains 84681 speed tests at this point.

4.6.4 Suspicious dates or times

We count the number of tests per day for the months January, February and March of 2015. Again we are looking at any suspicious peaks in the data?



We find no disturbing or unknown peaks on a specific date.

	01 januari	02 februari	03 maart	Sum
KPN NL	8801	8137	9310	26248
T-Mobile NL	10877	9361	11721	31959
Vodafone NL	9511	7804	9159	26474
Sum	29189	25302	30190	84681

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 Download speed(Kbps)
KPN NL	01 januari	22177.8
KPN NL	02 februari	20368.4
KPN NL	03 maart	20422.1
T-Mobile NL	01 januari	36838.3
T-Mobile NL	02 februari	36307.0
T-Mobile NL	03 maart	39148.8
Vodafone NL	01 januari	25808.6
Vodafone NL	02 februari	25731.6

Operator	Month	Average Download speed(Kbps)
Vodafone NL	03 maart	27323.7

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

Table below shows details for upload speed.

Operator	Month	Average Upload speed(Kbps)
KPN NL	01 januari	9725.1
KPN NL	02 februari	7593.4
KPN NL	03 maart	7687.4
T-Mobile NL	01 januari	17362.7
T-Mobile NL	02 februari	17410.3
T-Mobile NL	03 maart	17275.2
Vodafone NL	01 januari	13415.3
Vodafone NL	02 februari	13016.3
Vodafone NL	03 maart	13645.0

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

Table below shows details for latency.

Operator	Month	Average Latency(ms)
KPN NL	01 januari	44.1
KPN NL	02 februari	45.9
KPN NL	03 maart	46.6
T-Mobile NL	01 januari	38.6
T-Mobile NL	02 februari	40.8
T-Mobile NL	03 maart	41.1
Vodafone NL	01 januari	48.2
Vodafone NL	02 februari	46.0
Vodafone NL	03 maart	48.3

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.

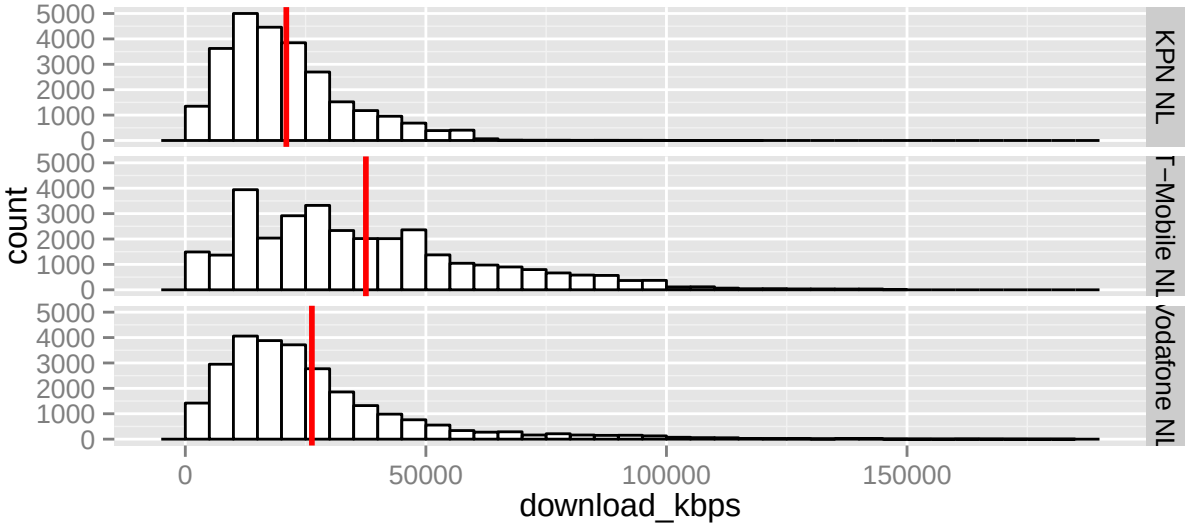
So how are the different metrics distributed?

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

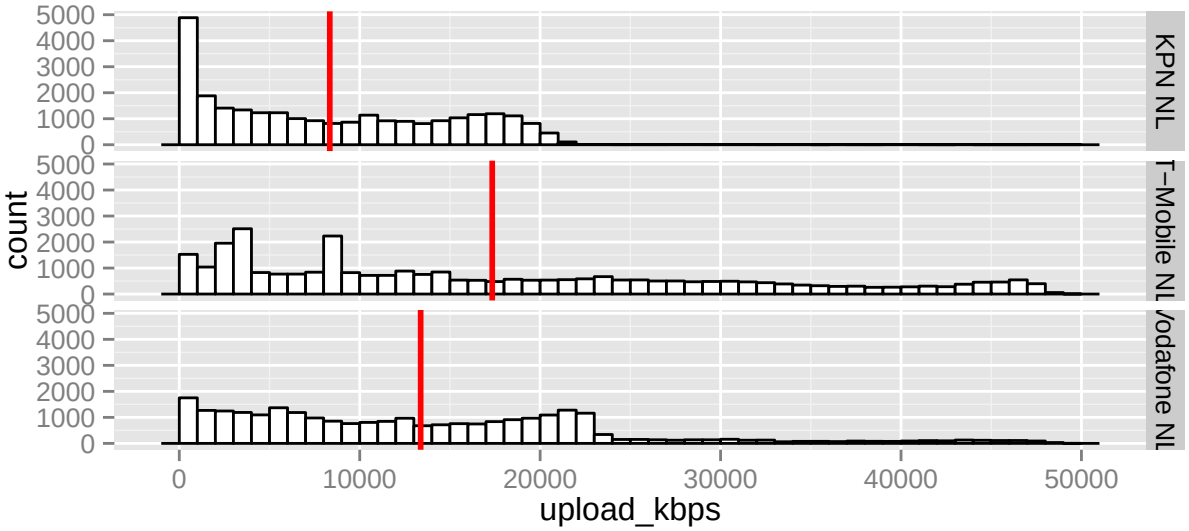
In the histogram below we see download speed in KBps on the horizontal axis. The number of test cases are plotted as bars, on the vertical axis we see the count of the number of speed tests in a specific bin (or range). The histogram gives a visual representation of the distribution of the data.



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

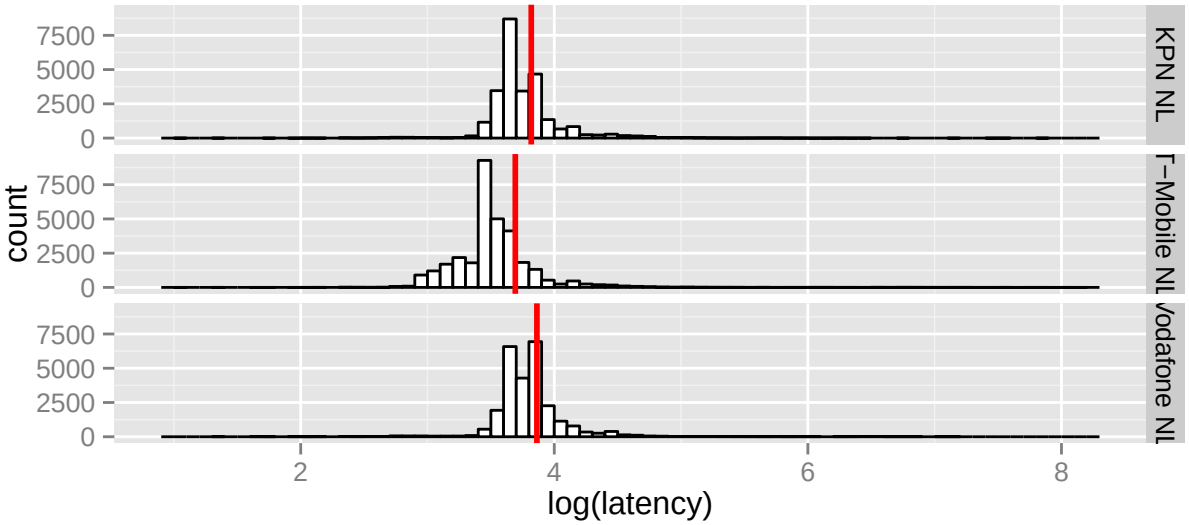
In the histogram below we see upload speed in KBps on the horizontal axis. The number of test cases are plotted as bars, on the vertical axis we see the count of the number of speed tests in a specific bin (or range). The histogram gives a visual representation of the distribution of the data.



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 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 upload speed as well.

5.1.3 Latency

In the histogram below we see log(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.



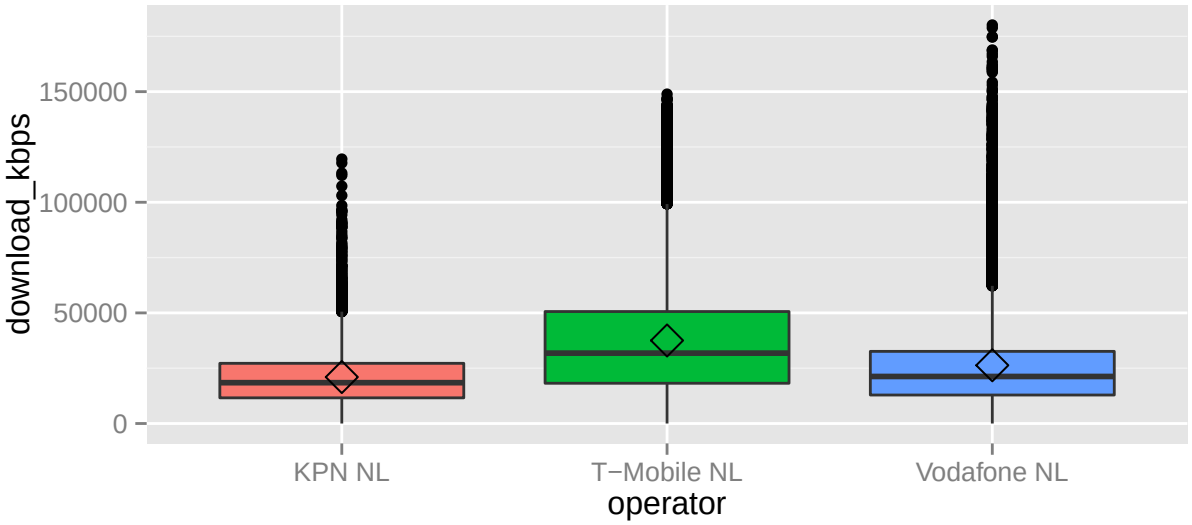
For latency smaller is better, so in this plot we are looking at which operator has the smallest latency. Again we see the red lines per operator. The x axis are on a log scale to these are factors of ten. The average latency(red line) for T-Mobile is the most to the left, which means T-Mobile has the 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 daimond 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:

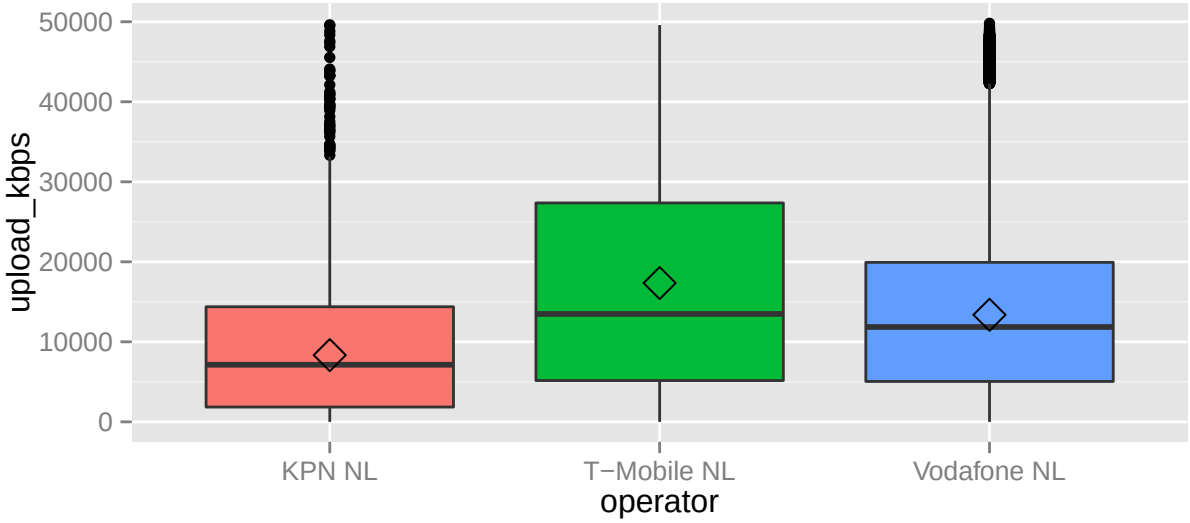
operator	10%	5%	1%
KPN NL	39666	47011	58652
T-Mobile NL	74088	86777	108484
Vodafone NL	50811	69454	104067

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 daimond 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	17977	19167	20799
T-Mobile NL	39883	44700	47235
Vodafone NL	24127	34539	45654

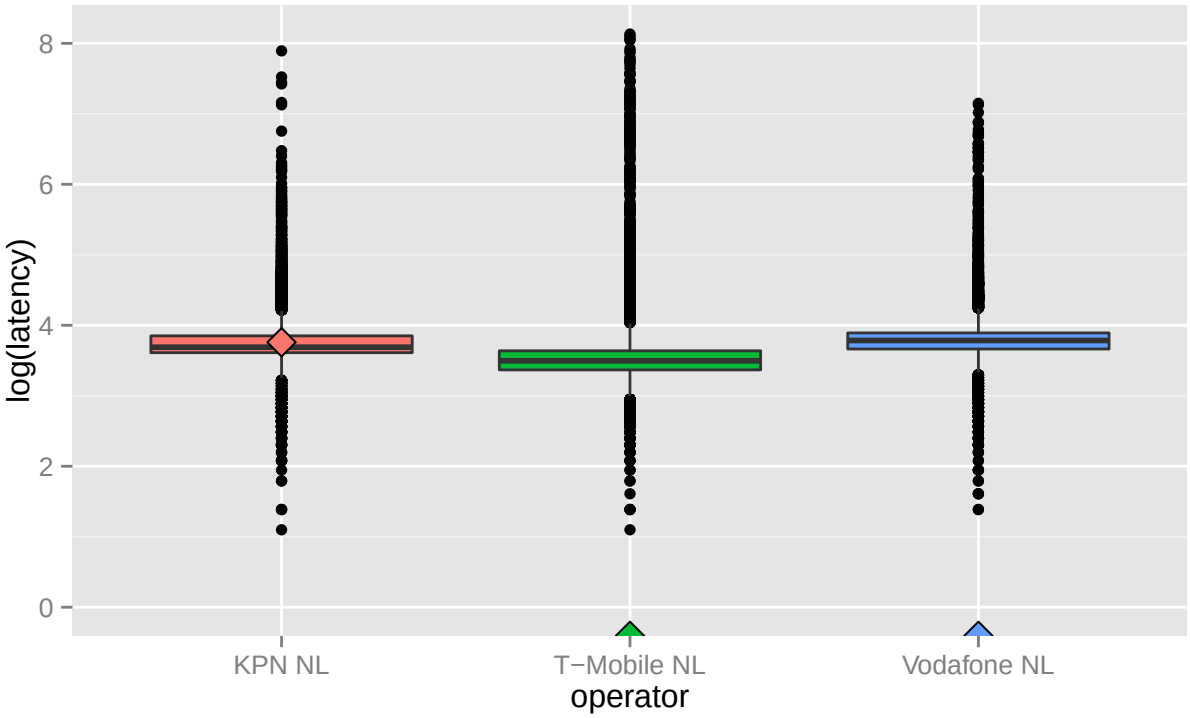
Table 12: Top percentiles average upload speed(Kbps)

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 daimond 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 latancy 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 latancy 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 84681 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 then 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 then 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 then 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	31959	37530	26248	20994	< 2.22e-16	Yes	16535.9	+/- 415.4	78.8
T-Mobile	Vodafone	31959	37530	26474	26310	< 2.22e-16	Yes	11220	+/- 489.8	42.6

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	31959	17345	26248	8341	< 2.22e-16	Yes	9003.1	+/- 226.5	107.9
T-Mobile	Vodafone	31959	17345	26474	13377	< 2.22e-16	Yes	3967.4	+/- 257.9	29.7

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	31959	40	26248	46	< 2.22e-16	Yes	-5.4	+/- 1.3	-11.9
T-Mobile	Vodafone	31959	40	26474	48	< 2.22e-16	Yes	-7.5	+/- 1.3	-15.8

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. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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 16.54 Mbps, which is 78.8%. Also, from the data analysed in the investigated area the average download speed of the 4G network of T-Mobile outperforms Vodafone by 11.22 Mbps, which is 42.6%. 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 km^2 of a total of 41545 km^2, which is 5.81%.

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

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	5113	40771	2013	21541	< 2.22e-16	Yes	19230	+/- 1232.8	89.3
T-Mobile	Vodafone	5113	40771	3434	33304	< 2.22e-16	Yes	7467.7	+/- 1449.9	22.4

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	5113	18831	2013	6897	< 2.22e-16	Yes	11934	+/- 632.8	173
T-Mobile	Vodafone	5113	18831	3434	15482	< 2.22e-16	Yes	3348.7	+/- 738.8	21.6

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	5113	36	2013	43	1.0171e-06	Yes	-7	+/- 3.7	-16.2
T-Mobile	Vodafone	5113	36	3434	45	2.3338e-11	Yes	-8.4	+/- 3.2	-18.8

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	2444	35716	1586	21236	< 2.22e-16	Yes	14480.5	+/- 1484.9	68.2
T-Mobile	Vodafone	2444	35716	1507	34797	0.27457	No	919.7	+/- 2169.2	NA

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	2444	18498	1586	8959	< 2.22e-16	Yes	9539.2	+/- 839.3	106.5
T-Mobile	Vodafone	2444	18498	1507	16198	7.7252e-08	Yes	2299.7	+/- 1100.6	14.2

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	2444	43	1586	46	0.16254	No	-2.9	+/- 5.4	NA
T-Mobile	Vodafone	2444	43	1507	48	0.034785	No	-4.6	+/- 5.6	NA

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	2126	34752	1533	17421	< 2.22e-16	Yes	17331.1	+/- 1564.8	99.5
T-Mobile	Vodafone	2126	34752	1297	30202	1.0229e-07	Yes	4550	+/- 2197.4	15.1

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	2126	19470	1533	8200	< 2.22e-16	Yes	11270	+/- 903.6	137.4
T-Mobile	Vodafone	2126	19470	1297	13838	< 2.22e-16	Yes	5631.9	+/- 1155	40.7

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	2126	37	1533	46	2.6819e-06	Yes	-9.6	+/- 5.2	-20.7
T-Mobile	Vodafone	2126	37	1297	49	9.9413e-13	Yes	-12.1	+/- 4.3	-24.7

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	1198	34787	824	20102	< 2.22e-16	Yes	14685.8	+/- 2147.4	73.1
T-Mobile	Vodafone	1198	34787	1142	31701	0.0024776	Yes	3086.1	+/- 2626.2	9.7

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	1198	17666	824	7099	< 2.22e-16	Yes	10566.9	+/- 1179.8	148.9
T-Mobile	Vodafone	1198	17666	1142	15644	0.0001314	Yes	2021.5	+/- 1360.6	12.9

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	1198	39	824	48	1.7272e-06	Yes	-9.3	+/- 5	-19.3
T-Mobile	Vodafone	1198	39	1142	46	0.0001401	Yes	-6.7	+/- 4.5	-14.7

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	930	35393	692	22225	< 2.22e-16	Yes	13167.2	+/- 2308.1	59.2
T-Mobile	Vodafone	930	35393	824	23160	< 2.22e-16	Yes	12233.1	+/- 2538.9	52.8

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	930	17650	692	9814	< 2.22e-16	Yes	7836	+/- 1293.7	79.8
T-Mobile	Vodafone	930	17650	824	14050	1.1732e-11	Yes	3600.1	+/- 1358.7	25.6

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	930	40	692	45	0.021003	No	-5.6	+/- 6.2	NA
T-Mobile	Vodafone	930	40	824	48	0.00030102	Yes	-8.6	+/- 6.1	-17.8

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	488	38980	372	21647	< 2.22e-16	Yes	17332.5	+/- 3454.5	80.1
T-Mobile	Vodafone	488	38980	370	23337	< 2.22e-16	Yes	15642.7	+/- 4104.6	67

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	488	17135	372	10157	< 2.22e-16	Yes	6977.8	+/- 1768.1	68.7
T-Mobile	Vodafone	488	17135	370	13465	2.4283e-06	Yes	3670.7	+/- 1996.6	27.3

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	488	39	372	45	0.00065833	Yes	-6.1	+/- 4.6	-13.5
T-Mobile	Vodafone	488	39	370	48	5.752e-08	Yes	-9.4	+/- 4.4	-19.5

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	559	33354	657	19479	< 2.22e-16	Yes	13874.8	+/- 2700.6	71.2
T-Mobile	Vodafone	559	33354	598	20106	< 2.22e-16	Yes	13247.7	+/- 2677	65.9

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	559	15450	657	9300	< 2.22e-16	Yes	6150.1	+/- 1537.3	66.1
T-Mobile	Vodafone	559	15450	598	11758	1.573e-08	Yes	3691.2	+/- 1670.7	31.4

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	559	45	657	44	0.5975	No	1.5	+/- 7.5	NA
T-Mobile	Vodafone	559	45	598	51	0.064212	No	-5.5	+/- 7.7	NA

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	533	35053	429	19379	< 2.22e-16	Yes	15674.5	+/- 3120.6	80.9
T-Mobile	Vodafone	533	35053	594	21300	< 2.22e-16	Yes	13753.1	+/- 3191.2	64.6

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	533	15157	429	7025	< 2.22e-16	Yes	8131.5	+/- 1694.8	115.7
T-Mobile	Vodafone	533	15157	594	10398	1.4283e-12	Yes	4759.2	+/- 1709.6	45.8

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	533	40	429	45	0.11369	No	-5.1	+/- 8.4	NA
T-Mobile	Vodafone	533	40	594	47	0.017272	No	-7.6	+/- 8.2	NA

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	591	40462	352	19903	< 2.22e-16	Yes	20558.8	+/- 3220.9	103.3
T-Mobile	Vodafone	591	40462	351	22171	< 2.22e-16	Yes	18290.5	+/- 3598.5	82.5

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	591	19423	352	8491	< 2.22e-16	Yes	10931.9	+/- 1838	128.7
T-Mobile	Vodafone	591	19423	351	11270	< 2.22e-16	Yes	8153.8	+/- 2106.5	72.4

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	591	38	352	47	4.2336e-06	Yes	-9.2	+/- 5.1	-19.5
T-Mobile	Vodafone	591	38	351	48	2.2395e-05	Yes	-9.6	+/- 5.8	-20.2

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	360	31023	374	22954	4.5614e-10	Yes	8068.7	+/- 3294.2	35.2
T-Mobile	Vodafone	360	31023	346	22774	8.3285e-11	Yes	8248.8	+/- 3226.2	36.2

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	360	15055	374	8735	3.3758e-16	Yes	6320.2	+/- 1939.5	72.4
T-Mobile	Vodafone	360	15055	346	13895	0.15949	No	1160.8	+/- 2129.2	NA

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	360	35	374	47	< 2.22e-16	Yes	-12.4	+/- 3.3	-26.4
T-Mobile	Vodafone	360	35	346	47	4.9181e-06	Yes	-12.4	+/- 6.9	-26.4

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	418	28274	306	19966	1.1046e-13	Yes	8308.4	+/- 2831.6	41.6
T-Mobile	Vodafone	418	28274	271	23011	3.7489e-05	Yes	5263.6	+/- 3275.7	22.9

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	418	15841	306	9698	2.6727e-14	Yes	6143.1	+/- 2038	63.3
T-Mobile	Vodafone	418	15841	271	12199	9.1277e-05	Yes	3642.7	+/- 2390.4	29.9

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	418	39	306	47	0.01837	No	-8.1	+/- 8.9	NA
T-Mobile	Vodafone	418	39	271	49	0.00079644	Yes	-10.8	+/- 8.3	-21.8

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	560	34408	491	21395	< 2.22e-16	Yes	13013.7	+/- 2841.2	60.8
T-Mobile	Vodafone	560	34408	377	22349	< 2.22e-16	Yes	12059.3	+/- 3131.3	54

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	560	15897	491	9353	< 2.22e-16	Yes	6544.6	+/- 1702.4	70
T-Mobile	Vodafone	560	15897	377	11834	7.8134e-08	Yes	4063.7	+/- 1937.2	34.3

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	560	38	491	47	1.9651e-05	Yes	-9.3	+/- 5.6	-19.6
T-Mobile	Vodafone	560	38	377	53	8.6388e-12	Yes	-14.4	+/- 5.4	-27.4

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	538	46356	356	21371	< 2.22e-16	Yes	24985.5	+/- 3711.4	116.9
T-Mobile	Vodafone	538	46356	428	16952	< 2.22e-16	Yes	29403.9	+/- 3675.9	173.5

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	538	21639	356	6674	< 2.22e-16	Yes	14965.7	+/- 1845.8	224.2
T-Mobile	Vodafone	538	21639	428	9439	< 2.22e-16	Yes	12200	+/- 1954.6	129.2

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	538	40	356	45	0.026706	No	-5.6	+/- 6.5	NA
T-Mobile	Vodafone	538	40	428	43	0.13256	No	-3.7	+/- 6.3	NA

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	599	30499	550	21320	< 2.22e-16	Yes	9178.5	+/- 2513.2	43.1
T-Mobile	Vodafone	599	30499	459	22831	4.7645e-08	Yes	7667.8	+/- 3593.9	33.6

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	599	15619	550	10682	9.4842e-16	Yes	4936.9	+/- 1557.6	46.2
T-Mobile	Vodafone	599	15619	459	12291	2.1371e-06	Yes	3328.1	+/- 1801.8	27.1

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	599	34	550	42	< 2.22e-16	Yes	-7.8	+/- 1.7	-18.5
T-Mobile	Vodafone	599	34	459	44	< 2.22e-16	Yes	-10	+/- 2.6	-22.5

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	335	30536	393	20355	7.558e-14	Yes	10181.3	+/- 3421.5	50
T-Mobile	Vodafone	335	30536	398	22704	1.9166e-08	Yes	7832.4	+/- 3550.1	34.5

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	335	15276	393	6495	< 2.22e-16	Yes	8780.6	+/- 1988.2	135.2
T-Mobile	Vodafone	335	15276	398	11296	1.5549e-06	Yes	3980.3	+/- 2118.5	35.2

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	335	39	393	50	0.0010665	Yes	-11	+/- 8.6	-22.1
T-Mobile	Vodafone	335	39	398	46	1.3355e-11	Yes	-6.9	+/- 2.6	-15.1

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	321	35373	243	20308	< 2.22e-16	Yes	15065	+/- 4120.6	74.2
T-Mobile	Vodafone	321	35373	295	20660	< 2.22e-16	Yes	14712.6	+/- 3945.7	71.2

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	321	17130	243	7039	< 2.22e-16	Yes	10091.3	+/- 2218.7	143.4
T-Mobile	Vodafone	321	17130	295	14717	0.013395	No	2412.6	+/- 2513.3	NA

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	321	40	243	43	0.47717	No	-3.6	+/- 13	NA
T-Mobile	Vodafone	321	40	295	46	0.2202	No	-6.8	+/- 14.4	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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	657	38864	556	19294	< 2.22e-16	Yes	19569.7	+/- 2730.1	101.4
T-Mobile	Vodafone	657	38864	646	27694	< 2.22e-16	Yes	11170	+/- 3199.6	40.3

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	657	17793	556	5907	< 2.22e-16	Yes	11886.1	+/- 1576	201.2
T-Mobile	Vodafone	657	17793	646	13652	3.5088e-10	Yes	4141	+/- 1687.4	30.3

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	657	41	556	43	0.61922	No	-1.6	+/- 8.3	NA
T-Mobile	Vodafone	657	41	646	51	0.0073601	Yes	-9.9	+/- 9.5	-19.5

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	351	37852	428	24363	1.154e-15	Yes	13489.1	+/- 4213.3	55.4
T-Mobile	Vodafone	351	37852	398	26991	1.3152e-09	Yes	10861.5	+/- 4555.7	40.2

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	351	17205	428	11461	2.504e-12	Yes	5743.6	+/- 2065.5	50.1
T-Mobile	Vodafone	351	17205	398	11885	7.8377e-10	Yes	5320.5	+/- 2198.6	44.8

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	351	38	428	47	1.4176e-12	Yes	-8.8	+/- 3.2	-18.7
T-Mobile	Vodafone	351	38	398	48	< 2.22e-16	Yes	-9.5	+/- 2.8	-20

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	369	41549	279	18162	< 2.22e-16	Yes	23387	+/- 3908.4	128.8
T-Mobile	Vodafone	369	41549	254	23845	< 2.22e-16	Yes	17703.6	+/- 5163.5	74.2

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	369	18936	279	7670	< 2.22e-16	Yes	11266.2	+/- 2207.6	146.9
T-Mobile	Vodafone	369	18936	254	14951	0.00048064	Yes	3985.4	+/- 2933.2	26.7

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	369	36	279	42	0.077805	No	-6.1	+/- 8.9	NA
T-Mobile	Vodafone	369	36	254	52	8.1805e-05	Yes	-16.2	+/- 10.5	-30.9

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	399	31197	143	22721	4.3237e-08	Yes	8475.6	+/- 3926.1	37.3
T-Mobile	Vodafone	399	31197	913	34553	0.017463	No	-3356.3	+/- 3638.1	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	399	13247	143	10785	0.0017979	Yes	2461.9	+/- 2027.5	22.8
T-Mobile	Vodafone	399	13247	913	15895	3.2162e-05	Yes	-2648.2	+/- 1634.4	-20

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	399	63	143	70	0.033528	No	-7.6	+/- 9.2	NA
T-Mobile	Vodafone	399	63	913	60	0.39254	No	3.2	+/- 9.6	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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).

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	7734	40284	15008	22403	< 2.22e-16	Yes	17880.6	+/- 799.4	79.8
T-Mobile	Vodafone	7734	40284	13950	25164	< 2.22e-16	Yes	15119.6	+/- 861.6	60.1

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	7734	17178	15008	8288	< 2.22e-16	Yes	8890.7	+/- 429.9	107.3
T-Mobile	Vodafone	7734	17178	13950	13090	< 2.22e-16	Yes	4088.5	+/- 457.6	31.2

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	7734	38	15008	43	8.7996e-14	Yes	-5.7	+/- 2	-13.2
T-Mobile	Vodafone	7734	38	13950	47	< 2.22e-16	Yes	-9.6	+/- 2	-20.3

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 mean divided by the slower of the two operators average speed. If the difference is not significant (column Sign is No), this column will state NA (not applicable). The comparison rules are similar to what is explained in the Diff(in Kbps or ms).