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

Hugo Koopmans

06-07-2015

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 standards. The analysis was performed by generally accepted and approved standards and statistical methods using open source tools.

We let the data speak for itself.

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

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

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

0.2 Code generation

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

1 Abstract

In this document we have conducted a statistical analysis of Ookla's NetMetrics data from speedtest.net. Ookla provides commercially available speed test data collected by their mobile app on the three main mobile platforms, Android, iOS and Windows mobile. We will load all the raw speed test data into a database, analyse the data 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 April, May and June 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 Q2 2015 so the months April, May and June 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 Q2/2015.

Table 1: Raw test data counts

	Counts
Android	179406
iOS	109980
Windows	7438
Sum	296824

So we start this analysis with in total 296824 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.

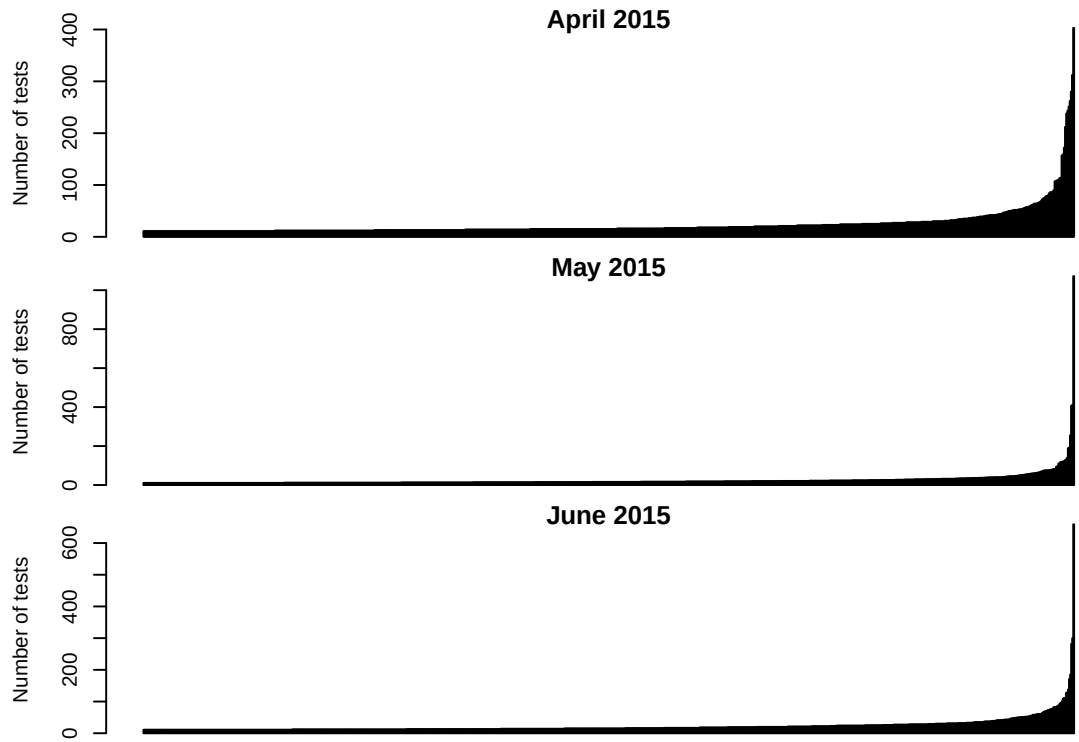
First of all, the names for the individual operators are spelled in various ways (e.g. 'T-Mobile NL', 'T-Mobile NL'). Next, we need to map connection types to the specific technology used (2G, 3G or 4G) depending on the operating system of the device. For more details on these transformations, please 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 122 devices in April, 140 devices in May and 133 devices in June, which in total represent 23456 speed tests. After filtering these devices the data set has 296824-23456=273368 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 861 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. There are 6534 tests with no identifiable operator. We will filter out all but the top 3 operators and proceed with speed tests from these top three operators.

Table 2: Most frequent operators

Operator	Number of speedtests
KPN NL	83767
T-Mobile NL	57738
Vodafone NL	54468
	6534
Carrier	5481
Tele2 NL	5369
TURKCELL	5005
DiGi	3923

Operator	Number of speedtests
Telfort NL	2667
TIGO	2500

The top three operators together are good for 195973 tests conducted all over the Netherlands in the test period of Q2 2015. We keep only speed tests from the top three operators.

This leaves 273368 - 77395 = 195973 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.

Table 3: Technology used in tests

	Number of cases	Percentage
2G	2240	1.14
3G	44394	22.65
4G	148824	75.94
UNKNOWN	183	0.09
WIFI/CELL	332	0.17

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

Filtering on 4G technology leaves 148824 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	42130	27157	25704
iOS	39185	29422	27175
Windows	2452	1159	1589

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 Q2 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 Q2 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	37777
52.35 , 4.9167	2235
52.3666 , 4.9027	547
51.9167 , 4.5	453
52.0938 , 5.1191	165
52.0833 , 4.3	162
51.8833 , 4.5333	129
52.0537 , 4.4924	73
52.1583 , 4.4931	69
51.8796 , 4.5059	67
52.4385 , 4.8264	66
51.8811 , 4.4569	64
52.3881 , 5.2354	59
51.8425 , 5.8528	54
51.81 , 4.6736	53

We asked for an explanation from Ookla on frequent and rounded coordinates.

Coordinate (52.3667,4.9) : 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 (52.3666-4.9027) is also in Amsterdam(Waterloo plein).

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 37777 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".

Head office locations We removed 38 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.

We did the same for locations close to the head offices of KPN and Vodafone. We removed 33 tests from the co-ordinates "52.0666 4.3479" (KPN office) and we removed 14 tests from the coordinates "52.3767 4.9061"" (Vodafone office Amsterdam).

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 tests from the coordinates around the head-offices of the top three providers as described in the above paragraph, together with 37777 from the coordinates "52.3667 , 4.9" the data set contains 148824 - = 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.

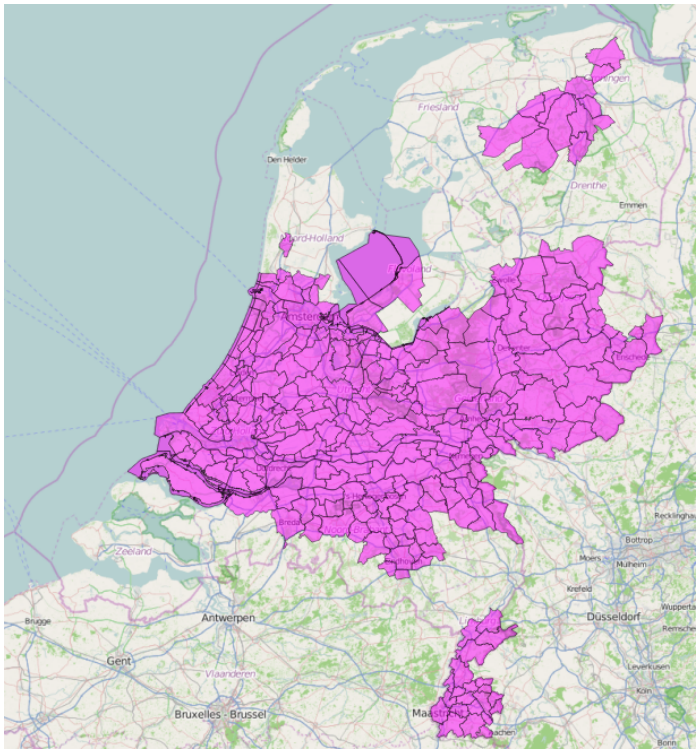
From T-Mobile we received a list of cities that, at the time of testing, have 4G coverage. From the data we can see that per city each provider has sufficient number of speed tests in the data set for the tests to be representative.

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 Q2 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.

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

	Number of tests	percentage
KPN NL	38200	39.04
T-Mobile NL	33261	33.99
Vodafone NL	26382	26.96
Sum	97843	100.00

Areas where T-Mobile announced 4G coverage in Q2 2015: Helmond,Schijndel,Sint-Oedenrode,Son en Breugel, Uden, Veghel, Laarbeek, Landerd, Bernheze, Landgraaf, Brunssum, Heerlen, Kerkrade and Schinnen were added in April ; Leek, Marum, Ooststellingwerf, Opsterland, Assen, Noordenveld, Brummen, Doesburg, Doetinchem, Duiven, Rheden, Westervoort, Zevenaar, Lingewaard, Montferland, Beek, Meerssen, Nuth, Stein, Voerendaal and Valkenburg aan de Geul were added in May; Dalfsen, Hardenberg, Hellendoorn, Ommen, Raalte, Heerde, Twenterand, Olst-Wijhe, Onderbanken, Roermond, Maasgouw, Roerdalen, Echt-Susteren, Sittard-Geleen, Groesbeek, Ubbergen, Boxmeer, Grave, Mill en Sint Hubert, Bergen (L.), Gennep, Mook en Middelaar, Cuijk, Sint Anthonis, Haaksbergen, Rijnwaarden, Aalten, Millingen aan de Rijn, Winterswijk, Oude IJsselstreek, Oost Gelre, Hof van Twente, Berkelland and Bronckhorst were added in June. All other cities in the TMNL coverage area had 4G enabled prior to Q2 2015.

Naturally, in the cities where 4G was announced in Q2, almost all of T-Mobile's 4G speedtests occur after announcing to customers that 4G is activated, so April, May or June 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 Q2/2015. 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 - = 97843 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 4 cases, for Vodafone we removed 1 cases and for KPN we removed 3 cases, because they where above 150(or 225) MBps.

After removing in total 8 of these suspicious measurements, the data set contains 97835 speed tests at this point.

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

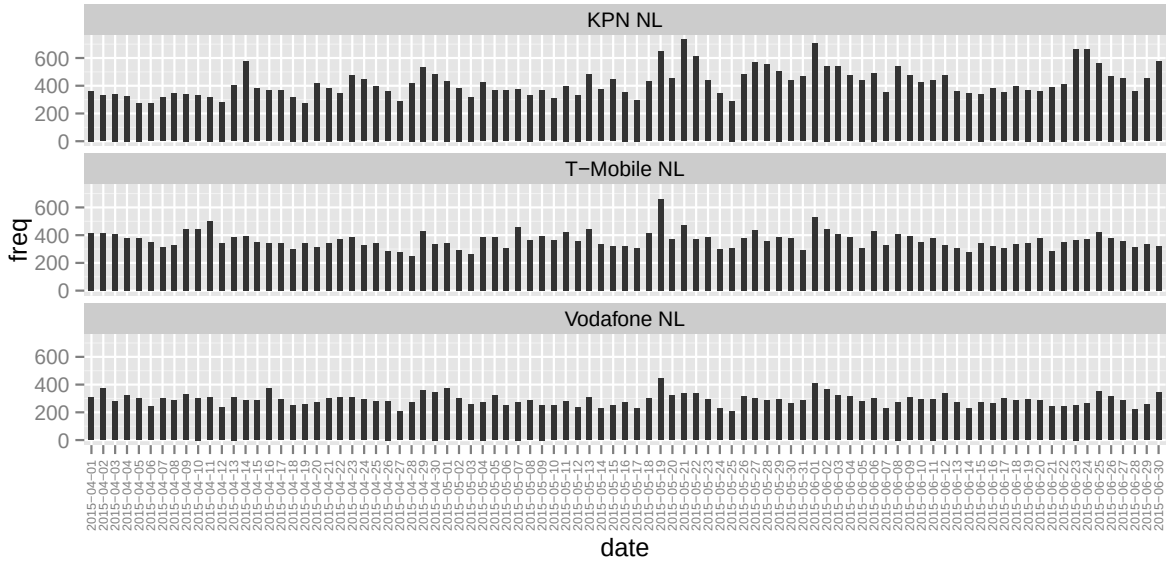
The maximum theoretical upload speed is for all operators the same: maximum upload speed of 50Mbps.

So again we remove suspicious measurements in which the **upload** speed exceeded the maximum theoretical speed per individual operator. For T-Mobile we removed 32 cases, for Vodafone we removed 21 cases and for KPN we removed 33 cases.

After removing in total 86 of these suspicious measurements the data set contains 97749 speed tests at this point.

4.6.4 Suspicious dates or times

We count the number of tests per day for the months April, May and June of 2015. Again we are looking at any suspicious peaks in the data.



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

Table 7: Counts per operator per month

	04 april	05 mei	06 juni	Sum
KPN NL	11056	13312	13796	38164
T-Mobile NL	10819	11587	10819	33225
Vodafone NL	8832	8843	8685	26360
Sum	30707	33742	33300	97749

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. For KPN we see a large increase in download and upload speed between April and May, as well as reduced latency. This is probably a result of KPN adding a substantial amount of sites in the large cities by activating 4G on the 1800Mhz frequency. In May 2015, KPN also announced LTE-Advanced in the 7 largest cities in The Netherlands. This has an influence in the increased number of tests, shown in table 7. LTE advanced can also have a positive influence on average download speed, because it allows download speeds of up to 225Mbps, provided that the customer doing the tests has a device that can support this and the network conditions at the location allow this.

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

Operator	Month	Average Downloadspeed(Kbps)
KPN NL	04	20783.5
KPN NL	05	29417.4
KPN NL	06	33042.0
T-Mobile NL	04	40279.9
T-Mobile NL	05	39849.7
T-Mobile NL	06	40659.3

Operator	Month	Average Downloadspeed(Kbps)
Vodafone NL	04	28734.2
Vodafone NL	05	30226.2
Vodafone NL	06	31379.8

Table below shows details for upload speed.

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

Operator	Month	Average Uploadspeed(Kbps)
KPN NL	04	9907.6
KPN NL	05	13295.7
KPN NL	06	14439.8
T-Mobile NL	04	17713.7
T-Mobile NL	05	17407.0
T-Mobile NL	06	17210.1
Vodafone NL	04	13933.4
Vodafone NL	05	14229.6
Vodafone NL	06	14273.3

Table below shows details for latency.

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

Operator	Month	Average Latency(ms)
KPN NL	04	43.9
KPN NL	05	42.5
KPN NL	06	42.5
T-Mobile NL	04	37.4
T-Mobile NL	05	38.6
T-Mobile NL	06	37.4
Vodafone NL	04	45.7
Vodafone NL	05	44.7
Vodafone NL	06	45.7

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 for the period of Q2 2015.

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.

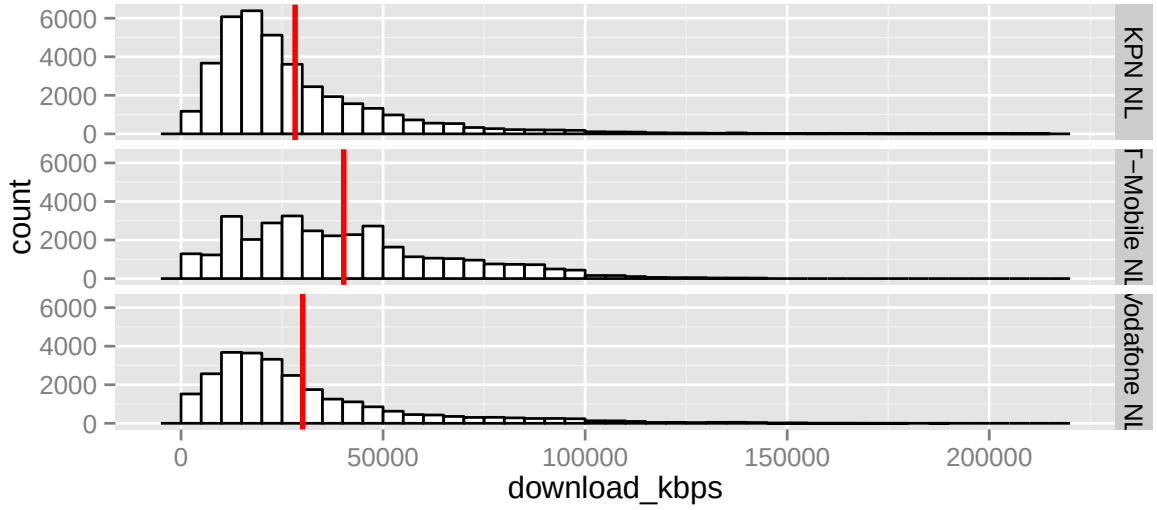
So how are the different metrics distributed?

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

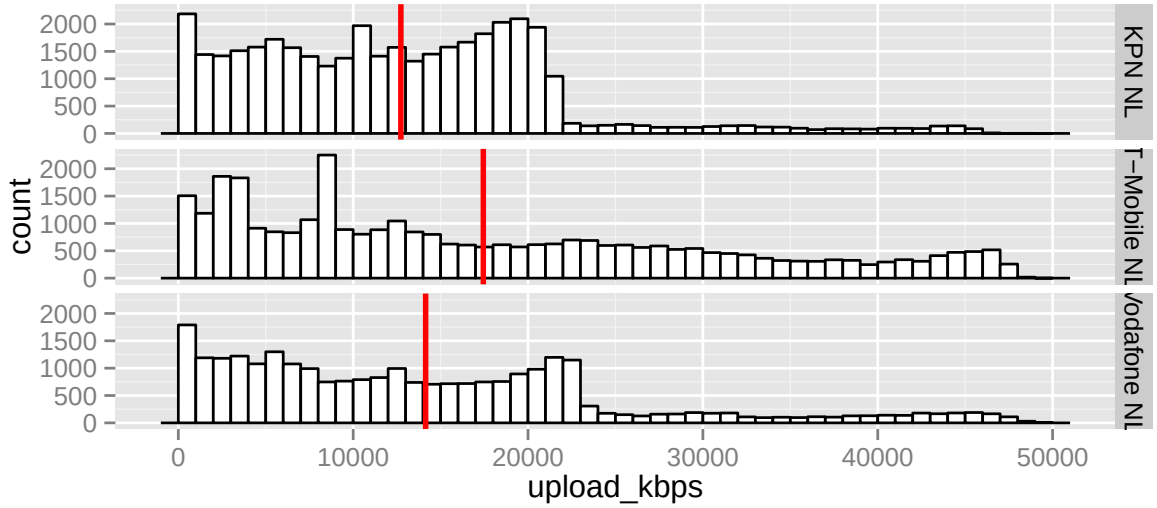
In the histogram below we see download speed in KBps on the horizontal axis. The number of test cases are plotted as bars, on the vertical axis we see the count of the number of speed tests in a specific bin (or range). The histogram gives a visual representation of the distribution of the data.



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

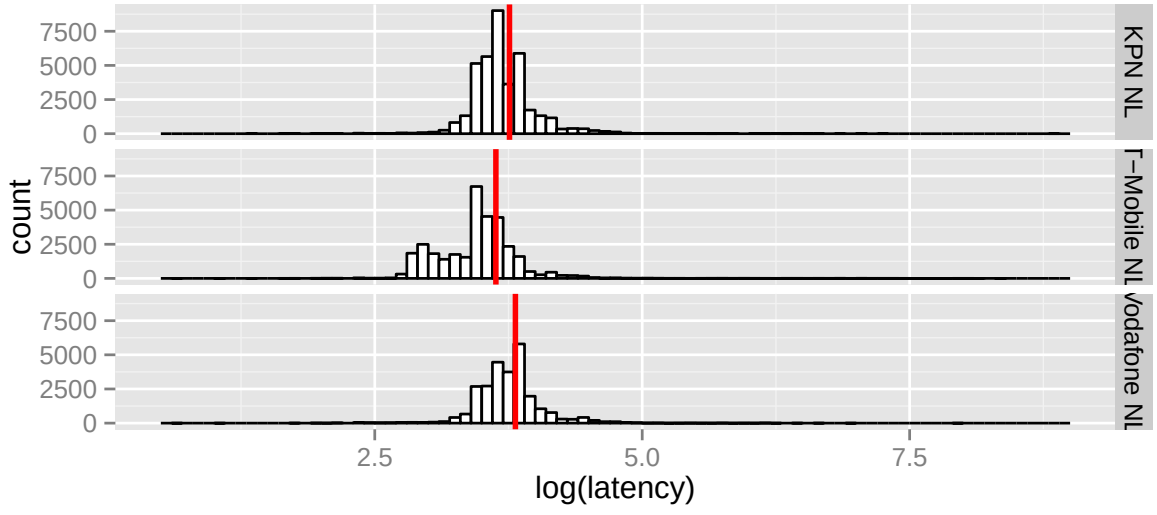
In the histogram below we see upload speed in KBps on the horizontal axis. The number of test cases are plotted as bars, on the vertical axis we see the count of the number of speed tests in a specific bin (or range). The histogram gives a visual representation of the distribution of the data.



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

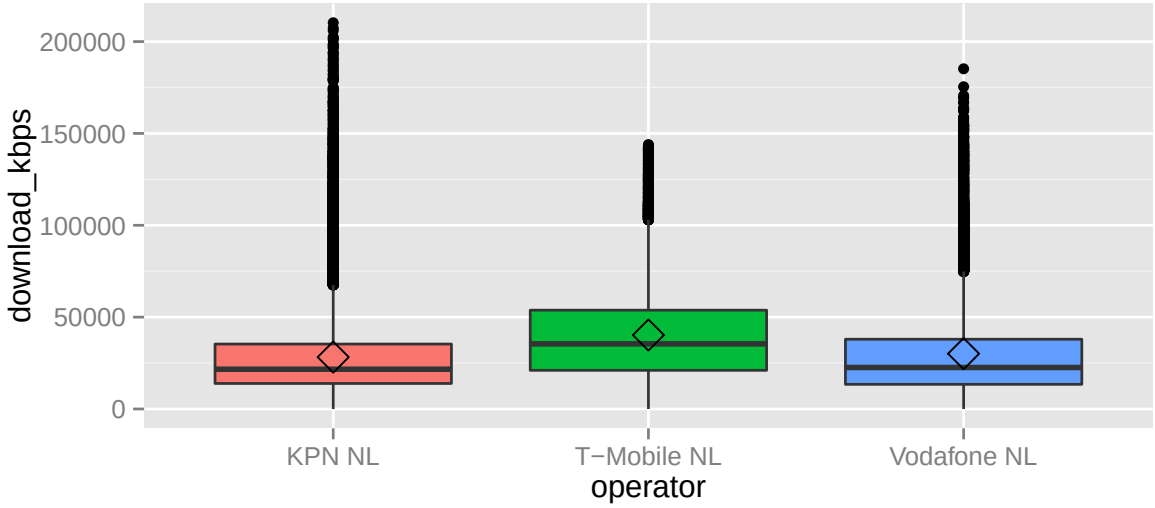
average latency(red line) for T-Mobile is the most to the left, which means T-Mobile has the smallest average latency of the three operators.

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:

Table 11: Top percentiles average download speed(Kbps)

operator	10%	5%	1%
KPN NL	55426	72091	113070
T-Mobile NL	78195	89428	110469
Vodafone NL	65308	86825	120910

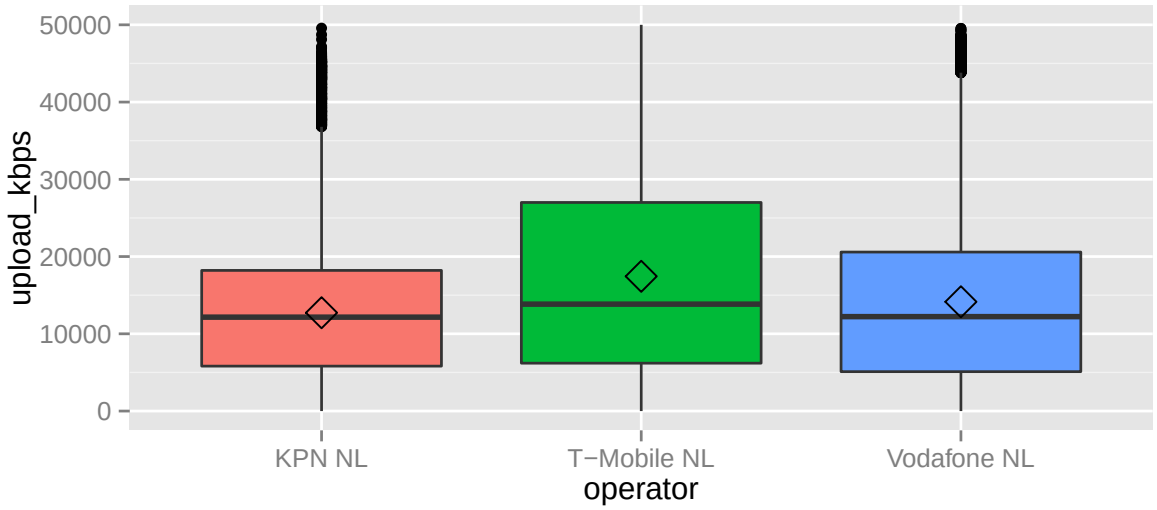
From the table we see that T-Mobile scores best in the 10% and 5% percentile of download speed tests per operator.

In the top 1% of download speed tests Vodafone scores best, followed by KPN. Both these operators they have the LTE-Advanced technology in some locations mostly in the largest cities. This technology is supported by a small number of devices. In excellent radio conditions and in case the user has a suitable device, download speeds higher than 150MBps (up to 225Mbps) can be achieved. This is the case in less than 1% of all tests of KPN and Vodafone, but also the main reason why the top 1% for these two

operators is higher than T-Mobile's. The LTE-advanced technology does not contribute to higher upload speeds nor lower latency.

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:

Table 12: Top percentiles average upload speed(Kbps)

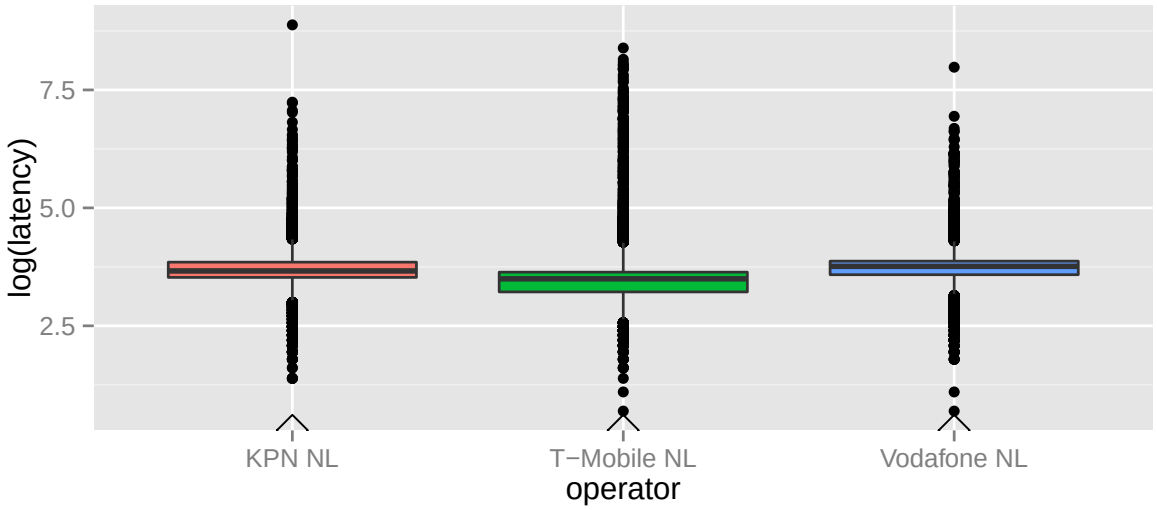
operator	10%	5%	1%
KPN NL	21043	28200	42945
T-Mobile NL	39097	44205	46896
Vodafone NL	29486	39893	46296

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 97749 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 cleaned data set, in the next chapter we test each individual city.

Let's see what our test results are:

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	33225	40253	38164	28226	< 2.22e-16	Yes	12027	+/- 467.9	42.6
T-Mobile	Vodafone	33225	40253	26360	30106	< 2.22e-16	Yes	10147	+/- 541.6	33.7

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	33225	17443	38164	12728	< 2.22e-16	Yes	4715	+/- 222.2	37
T-Mobile	Vodafone	33225	17443	26360	14145	< 2.22e-16	Yes	3298	+/- 260.9	23.3

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	33225	38	38164	43	< 2.22e-16	Yes	-5.1	+/- 1.3	-11.9
T-Mobile	Vodafone	33225	38	26360	45	< 2.22e-16	Yes	-7.6	+/- 1.2	-16.7

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 12.03 Mbps, which is 42.6%. Also, from the data analysed in the investigated area the average download speed of the 4G network of T-Mobile outperforms Vodafone by 10.15 Mbps, which is 33.7%. 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 21 cities per city

From CBS we have the following top 21 cities based on number of inhabitants("aantal inwoners") from 2014. We see that Zwolle is now number twenty in favour of Maastricht(now 21). For completness we keep Maastricht in the list of cities to be analysed.

gm_code	gm_naam	aant_inw	opp_land
GM0363	Amsterdam	810935	16589
GM0599	Rotterdam	618355	20888
GM0518	's-Gravenhage	508940	8187
GM0344	Utrecht	328165	9426
GM0772	Eindhoven	220920	8767
GM0855	Tilburg	210270	11724
GM0014	Groningen	198315	7827
GM0034	Almere	196010	12930
GM0758	Breda	179620	12605
GM0268	Nijmegen	168290	5361
GM0153	Enschede	158585	14099
GM0200	Apeldoorn	157545	33988
GM0392	Haarlem	155145	2922
GM0307	Amersfoort	150895	6282
GM0202	Arnhem	150820	9796
GM0479	Zaanstad	150595	7392
GM0394	Haarlemmermeer	144060	17868
GM0796	's-Hertogenbosch	143730	8440
GM0637	Zoetermeer	123560	3453
GM0193	Zwolle	123160	11131
GM0935	Maastricht	122485	5662

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 21 cities covers 5020400 out of 16828900 inhabitants. Which is 29.83 %. In terms of area this is 235337 km^2 of a total of 41545 km^2, which is 566.46%.

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	5012	42288	2672	31822	< 2.22e-16	Yes	10466.4	+/- 1687.5	32.9
T-Mobile	Vodafone	5012	42288	2890	38652	5.4369e-08	Yes	3635.7	+/- 1720.9	9.4

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	5012	18904	2672	13439	< 2.22e-16	Yes	5465.1	+/- 707.6	40.7
T-Mobile	Vodafone	5012	18904	2890	16992	1.4466e-09	Yes	1912.2	+/- 813.2	11.3

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	5012	34	2672	41	3.226e-09	Yes	-6.7	+/- 2.9	-16.5
T-Mobile	Vodafone	5012	34	2890	42	6.8797e-14	Yes	-7.5	+/- 2.6	-18.1

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 (colums 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	2401	39498	2025	35780	2.3722e-06	Yes	3718.3	+/- 2027.8	10.4
T-Mobile	Vodafone	2401	39498	1382	39046	0.6408	No	452.2	+/- 2498.2	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	2401	19390	2025	15013	< 2.22e-16	Yes	4377.1	+/- 933.1	29.2
T-Mobile	Vodafone	2401	19390	1382	17622	9.5404e-05	Yes	1768.1	+/- 1166.3	10

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	2401	37	2025	41	0.0082147	Yes	-4.2	+/- 4.1	-10.1
T-Mobile	Vodafone	2401	37	1382	43	0.00017652	Yes	-6	+/- 4.1	-13.9

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 (colums 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	1893	39992	2280	33708	4.7325e-15	Yes	6283.9	+/- 2059.4	18.6
T-Mobile	Vodafone	1893	39992	1177	36044	0.00010084	Yes	3947.5	+/- 2612.4	11

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	1893	20207	2280	15155	< 2.22e-16	Yes	5051.3	+/- 995.4	33.3
T-Mobile	Vodafone	1893	20207	1177	15369	< 2.22e-16	Yes	4838.2	+/- 1296.8	31.5

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	1893	38	2280	43	0.16349	No	-4.5	+/- 8.3	NA
T-Mobile	Vodafone	1893	38	1177	47	0.0090452	Yes	-8.4	+/- 8.3	-17.9

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 (colums 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	1045	37675	1377	33289	4.5912e-05	Yes	4385.9	+/- 2769	13.2
T-Mobile	Vodafone	1045	37675	1047	37923	0.83063	No	-248	+/- 2988.5	NA

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	1045	18067	1377	15024	7.217e-10	Yes	3043.6	+/- 1266.9	20.3
T-Mobile	Vodafone	1045	18067	1047	16551	0.0083012	Yes	1516.6	+/- 1479.9	9.2

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	1045	36	1377	42	0.00011519	Yes	-5.8	+/- 3.9	-13.7
T-Mobile	Vodafone	1045	36	1047	42	0.00014179	Yes	-5.9	+/- 4	-13.9

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

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

Explanation of terms

Sample 1: Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

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

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

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

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

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

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

Rel(%): Relative difference in percentage. It is calculated as the difference of the mean divided by the slower of the two operators average speed. If the difference is not significant (colums 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	744	41539	858	39485	0.12189	No	2053.8	+/- 3422.2	NA
T-Mobile	Vodafone	744	41539	842	33202	3.6011e-10	Yes	8336.1	+/- 3406.5	25.1

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	744	18622	858	16655	0.0013471	Yes	1967.1	+/- 1579.6	11.8
T-Mobile	Vodafone	744	18622	842	15610	6.7048e-07	Yes	3012	+/- 1556.4	19.3

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	744	41	858	44	0.48571	No	-2.6	+/- 9.7	NA
T-Mobile	Vodafone	744	41	842	49	0.031328	No	-8.2	+/- 9.8	NA

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 (colums 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	486	40094	553	33659	6.9534e-05	Yes	6435.6	+/- 4158	19.1
T-Mobile	Vodafone	486	40094	346	32889	0.00040144	Yes	7205.7	+/- 5232.1	21.9

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	486	15941	553	14929	0.1689	No	1012.4	+/- 1898.1	NA
T-Mobile	Vodafone	486	15941	346	13871	0.014233	No	2069.9	+/- 2175.5	NA

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	486	42	553	44	0.60324	No	-1.9	+/- 9.4	NA
T-Mobile	Vodafone	486	42	346	48	0.11551	No	-5.8	+/- 9.5	NA

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

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

Explanation of terms

Sample 1: Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

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

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

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

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

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

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

Rel(%): Relative difference in percentage. It is calculated as the difference of the mean divided by the slower of the two operators average speed. If the difference is not significant (colums 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	540	39799	894	33077	2.1557e-06	Yes	6721.4	+/- 3641.8	20.3
T-Mobile	Vodafone	540	39799	447	26705	< 2.22e-16	Yes	13093.4	+/- 3967.2	49

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	540	19883	894	13967	8.4047e-16	Yes	5916.4	+/- 1859.7	42.4
T-Mobile	Vodafone	540	19883	447	14326	9.8405e-12	Yes	5557	+/- 2080.3	38.8

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	540	40	894	43	0.20309	No	-2.5	+/- 5.2	NA
T-Mobile	Vodafone	540	40	447	46	0.0083408	Yes	-5.3	+/- 5.2	-11.6

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

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

Explanation of terms

Sample 1: Number of speedtest samples for operator 1.

Sample 2: Number of speedtest samples for operator 2.

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

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

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

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

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

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

Rel(%): Relative difference in percentage. It is calculated as the difference of the mean divided by the slower of the two operators average speed. If the difference is not significant (colums 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	413	40905	657	31310	5.4743e-09	Yes	9595	+/- 4207	30.6
T-Mobile	Vodafone	413	40905	393	28697	2.8881e-12	Yes	12207.4	+/- 4443.9	42.5

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	413	15041	657	13254	0.0093687	Yes	1786.4	+/- 1770.9	13.5
T-Mobile	Vodafone	413	15041	393	12455	0.0012006	Yes	2585.1	+/- 2053.5	20.8

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	413	34	657	41	1.0081e-05	Yes	-7.4	+/- 4.3	-18
T-Mobile	Vodafone	413	34	393	43	2.5929e-07	Yes	-9.6	+/- 4.7	-22.3

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 (colums 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	487	40572	458	23860	< 2.22e-16	Yes	16712.1	+/- 3311.6	70
T-Mobile	Vodafone	487	40572	289	26606	< 2.22e-16	Yes	13965.8	+/- 4113.2	52.5

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	487	19933	458	10943	< 2.22e-16	Yes	8989.4	+/- 1927.1	82.1
T-Mobile	Vodafone	487	19933	289	12816	4.4583e-14	Yes	7116.9	+/- 2388.4	55.5

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	487	36	458	43	7.0785e-06	Yes	-7.7	+/- 4.4	-17.7
T-Mobile	Vodafone	487	36	289	44	2.8842e-05	Yes	-8.3	+/- 5.1	-18.9

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 (colums 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	372	33370	629	30935	0.10961	No	2435.4	+/- 3925.4	NA
T-Mobile	Vodafone	372	33370	365	28516	0.0040842	Yes	4854.3	+/- 4351.9	17

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	372	15651	629	15421	0.76008	No	229.8	+/- 1943.1	NA
T-Mobile	Vodafone	372	15651	365	15108	0.52719	No	542.8	+/- 2215.9	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	372	34	629	44	6.3489e-08	Yes	-10.1	+/- 4.8	-22.9
T-Mobile	Vodafone	372	34	365	43	< 2.22e-16	Yes	-8.7	+/- 2.5	-20.4

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 (colums 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	314	31605	458	28260	0.045234	No	3345.4	+/- 4307.1	NA
T-Mobile	Vodafone	314	31605	169	20654	1.6378e-11	Yes	10951.1	+/- 4101.5	53

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	314	15933	458	13152	0.00076735	Yes	2781.2	+/- 2124.9	21.1
T-Mobile	Vodafone	314	15933	169	11840	1.9569e-05	Yes	4093.4	+/- 2453.5	34.6

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	314	35	458	44	2.062e-09	Yes	-9.3	+/- 4	-21.1
T-Mobile	Vodafone	314	35	169	45	< 2.22e-16	Yes	-10.6	+/- 3.1	-23.4

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 (colums 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	407	37286	640	27216	7.8507e-12	Yes	10070.1	+/- 3746.2	37
T-Mobile	Vodafone	407	37286	347	32404	0.0095307	Yes	4881.8	+/- 4850.5	15.1

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	407	17171	640	12604	3.9554e-10	Yes	4567.1	+/- 1856.2	36.2
T-Mobile	Vodafone	407	17171	347	13583	3.7824e-05	Yes	3587.9	+/- 2235.2	26.4

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	407	33	640	43	< 2.22e-16	Yes	-10.3	+/- 2.1	-23.8
T-Mobile	Vodafone	407	33	347	47	< 2.22e-16	Yes	-14.4	+/- 3.1	-30.4

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 (colums 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	506	43602	380	29520	9.7669e-14	Yes	14081.8	+/- 4800.6	47.7
T-Mobile	Vodafone	506	43602	312	23803	< 2.22e-16	Yes	19799.1	+/- 4586.3	83.2

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	506	19816	380	12440	< 2.22e-16	Yes	7375.9	+/- 2006.2	59.3
T-Mobile	Vodafone	506	19816	312	11467	< 2.22e-16	Yes	8349.2	+/- 2155.3	72.8

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

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	506	56	380	44	0.23112	No	12.5	+/- 27	NA
T-Mobile	Vodafone	506	56	312	40	0.11739	No	16	+/- 26.3	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 (colums 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 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	330	39856	528	22322	< 2.22e-16	Yes	17533.4	+/- 3866.4	78.5
T-Mobile	Vodafone	330	39856	349	27208	2.3479e-12	Yes	12647.7	+/- 4569.2	46.5

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	330	17486	528	12706	6.8616e-09	Yes	4780	+/- 2091.6	37.6
T-Mobile	Vodafone	330	17486	349	12712	1.3735e-07	Yes	4774.1	+/- 2312.1	37.6

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	330	48	528	42	0.40853	No	6.1	+/- 19.1	NA
T-Mobile	Vodafone	330	48	349	45	0.68676	No	3	+/- 19.3	NA

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 (colums 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 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	518	32852	600	24717	7.4637e-14	Yes	8135.3	+/- 2768.6	32.9
T-Mobile	Vodafone	518	32852	341	31110	0.36128	No	1742.2	+/- 4929.9	NA

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	518	17090	600	12050	3.3744e-15	Yes	5039.9	+/- 1620	41.8
T-Mobile	Vodafone	518	17090	341	12385	5.5739e-09	Yes	4704.2	+/- 2061.1	38

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	518	35	600	42	0.013416	No	-6.6	+/- 6.9	NA
T-Mobile	Vodafone	518	35	341	43	0.005195	Yes	-7.3	+/- 6.7	-17.1

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 (colums 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	393	42385	376	34649	0.00013576	Yes	7735.7	+/- 5207.1	22.3
T-Mobile	Vodafone	393	42385	279	31445	3.419e-07	Yes	10940	+/- 5475.5	34.8

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	393	18903	376	14240	8.5663e-08	Yes	4663.2	+/- 2226.5	32.7
T-Mobile	Vodafone	393	18903	279	16147	0.0080161	Yes	2756.1	+/- 2677.1	17.1

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	393	46	376	39	0.45062	No	7.5	+/- 25.8	NA
T-Mobile	Vodafone	393	46	279	40	0.51556	No	6.5	+/- 25.9	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 (colums 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	647	37229	749	27573	2.0309e-14	Yes	9655.6	+/- 3218.7	35
T-Mobile	Vodafone	647	37229	534	30404	3.1504e-06	Yes	6824.7	+/- 3759.2	22.4

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	647	17254	749	12454	8.3752e-15	Yes	4799.5	+/- 1572.1	38.5
T-Mobile	Vodafone	647	17254	534	14877	0.00072151	Yes	2376.1	+/- 1808.3	16

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	647	42	749	43	0.82888	No	-1	+/- 12.2	NA
T-Mobile	Vodafone	647	42	534	46	0.37769	No	-4.2	+/- 12.2	NA

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 (colums 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	301	41549	465	30581	7.1788e-09	Yes	10968.5	+/- 4827.2	35.9
T-Mobile	Vodafone	301	41549	389	42467	0.67326	No	-917.6	+/- 5618.3	NA

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	301	16811	465	13286	1.7563e-05	Yes	3525.7	+/- 2099.6	26.5
T-Mobile	Vodafone	301	16811	389	15768	0.27838	No	1043.6	+/- 2485.5	NA

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	301	37	465	42	0.069438	No	-4.5	+/- 6.4	NA
T-Mobile	Vodafone	301	37	389	45	0.0023604	Yes	-7.6	+/- 6.4	-16.9

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 (colums 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	409	40327	421	23938	< 2.22e-16	Yes	16389.7	+/- 3939.3	68.5
T-Mobile	Vodafone	409	40327	232	33467	0.0016308	Yes	6860.4	+/- 5599.2	20.5

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	409	19619	421	11922	< 2.22e-16	Yes	7696.7	+/- 1974	64.6
T-Mobile	Vodafone	409	19619	232	14230	4.4299e-07	Yes	5389.3	+/- 2723.9	37.9

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	409	38	421	43	0.048139	No	-5.4	+/- 7	NA
T-Mobile	Vodafone	409	38	232	48	0.00013624	Yes	-9.9	+/- 6.7	-20.8

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 (colums 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 Zwolle

The table shows the speed test analysis for gemeente Zwolle. 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	305	30325	410	18673	< 2.22e-16	Yes	11652.9	+/- 3467.2	62.4
T-Mobile	Vodafone	305	30325	280	25530	0.0017882	Yes	4795.6	+/- 3949.5	18.8

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	305	13442	410	9328	2.3008e-07	Yes	4114.6	+/- 2023.8	44.1
T-Mobile	Vodafone	305	13442	280	13043	0.65772	No	399.6	+/- 2329.7	NA

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	305	36	410	45	3.2143e-05	Yes	-8.5	+/- 5.2	-18.9
T-Mobile	Vodafone	305	36	280	46	1.5108e-09	Yes	-9.8	+/- 4.1	-21.2

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 (colums 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 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	355	41959	222	27578	3.2461e-16	Yes	14380.5	+/- 4406.9	52.1
T-Mobile	Vodafone	355	41959	657	41353	0.72466	No	606	+/- 4439.2	NA

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	355	19871	222	13969	8.3085e-13	Yes	5902.2	+/- 2080.7	42.3
T-Mobile	Vodafone	355	19871	657	17803	0.013513	No	2067.5	+/- 2156.6	NA

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	355	42	222	49	0.044371	No	-7.1	+/- 9.1	NA
T-Mobile	Vodafone	355	42	657	58	0.00031541	Yes	-15.6	+/- 11.1	-27

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 (colums 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).

9.22 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	8618	41583	17712	29258	< 2.22e-16	Yes	12325.8	+/- 854	42.1
T-Mobile	Vodafone	8618	41583	11447	29176	< 2.22e-16	Yes	12407.6	+/- 1075.3	42.5

Table 80: Comparison of means for metric: download(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	8618	17025	17712	12556	< 2.22e-16	Yes	4468.7	+/- 413.7	35.6
T-Mobile	Vodafone	8618	17025	11447	14022	< 2.22e-16	Yes	3002.6	+/- 462	21.4

Table 81: Comparison of means for metric: upload(kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	8618	38	17712	40	0.010134	No	-2.3	+/- 2.3	NA
T-Mobile	Vodafone	8618	38	11447	44	3.0854e-11	Yes	-6	+/- 2.3	-13.6

Table 82: 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 (colums 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).