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

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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 July, August and September 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 Q3 2015 so the months July, August and September 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 Q3/2015.

Table 1: Raw test data counts

	Counts
Android	183501
iOS	87184
Windows	7688
Sum	278373

So we start this analysis with in total 278373 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.

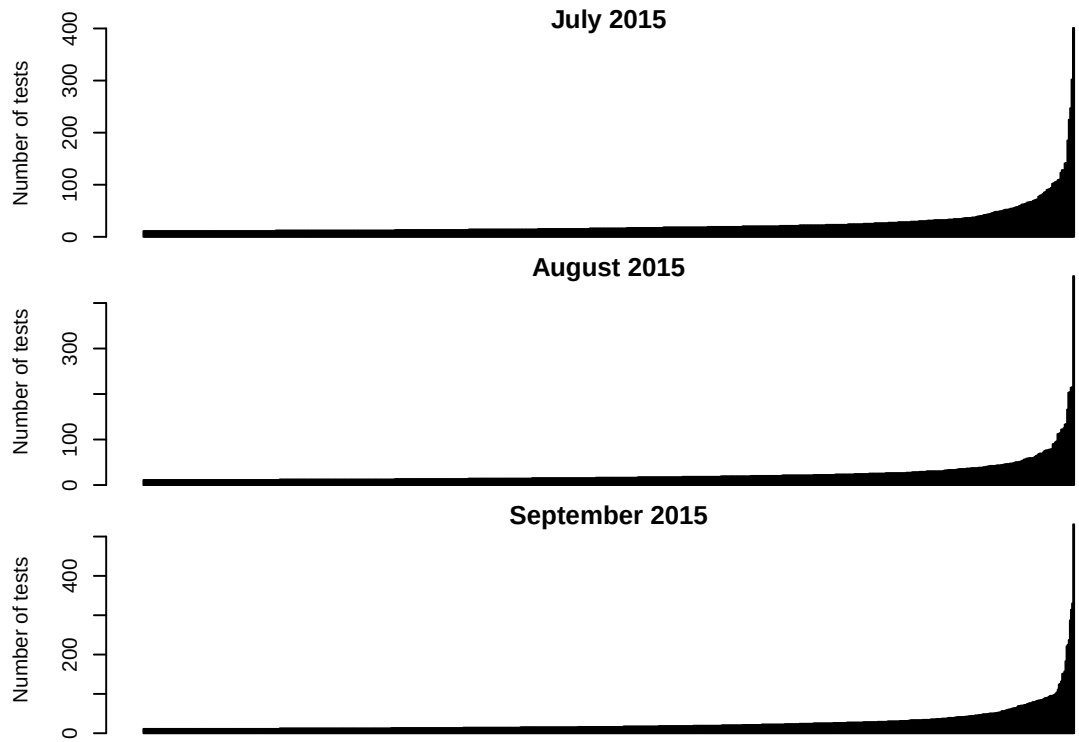
First of all, the names for the individual operators are spelled in various ways (e.g. 'T-Mobile NL', 'T-Mobile NL'). Next, we need to map connection types to the specific technology used (2G, 3G or 4G) depending on the operating system of the device. For more details on these transformations, please 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 112 devices in July, 123 devices in August and 169 devices in September, which in total represent 24138 speed tests. After filtering these devices the data set has 278373-24138=254235 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 898 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 7137 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	75152
T-Mobile NL	51078
Vodafone NL	47389
DiGi	7423
	7137
TELKOMSEL	4640
Tele2 NL	4167

Operator	Number of speedtests
Carrier	3609
TURKCELL	3538
TIGO	2857

The top three operators together are good for 173619 tests conducted all over the Netherlands in the test period of Q3 2015. We keep only speed tests from the top three operators.

This leaves 254235 - 80616 = 173619 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	1906	1.10
3G	37344	21.51
4G	133927	77.14
UNKNOWN	227	0.13
WIFI/CELL	215	0.12

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

Filtering on 4G technology leaves 133927 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	41896	25803	23426
iOS	31048	24115	22497
Windows	2208	1160	1466

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 Q3 2015, the period of the test. All of the top 21 cities in the Netherlands, which we will analyze per city, had 4G enabled prior to Q3 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	31605
52.374 , 4.8897	1640
52.3666 , 4.9027	826
51.9225 , 4.4792	170
52.0767 , 4.2986	122
52.35 , 4.9167	118
52.1583 , 4.4931	80
51.4408 , 5.4778	71
52 , 6	67
52.3808 , 4.6368	65
51.8425 , 5.8528	64
52.056 , 4.4983	63
51.81 , 4.6736	61
52.0833 , 5.0833	59
51.9167 , 4.4333	57

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 (52.374-4.8897) is also in Amsterdam(Spuistraat).

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 31605 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 47 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 14 tests from the co-ordinates "52.0666 4.3479" (KPN office) and we removed 5 tests from the coordinates "52.3767 4.9061"" (Vodafone office Amsterdam).

After removing 66 tests from the coordinates around the head-offices of the top three providers as described in the above paragraph, together with 31605 from the coordinates "52.3667 , 4.9" the data set contains 133927 - 31671 = 102256 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.

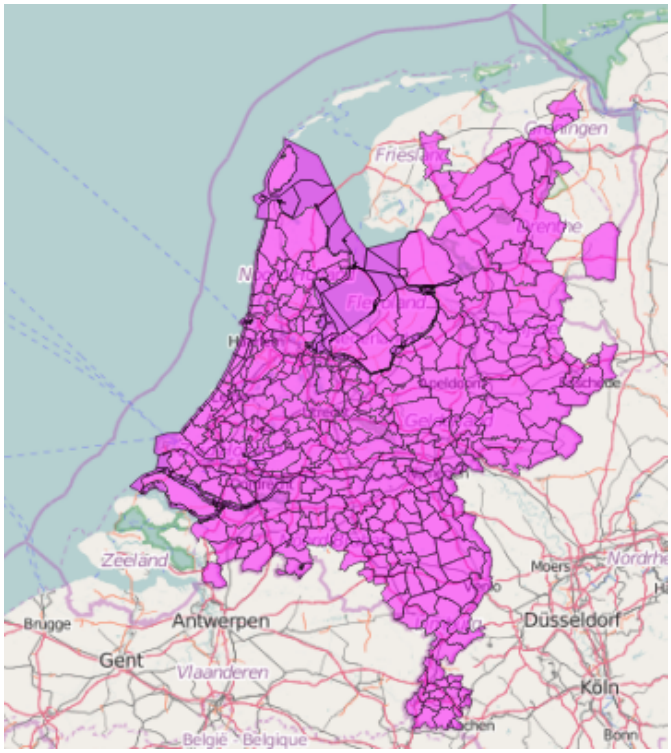
From T-Mobile we received a list of cities that, at the time of testing, have 4G coverage. From the data we can see that per city each provider has sufficient number of speed tests in the data set for the tests to be representative.

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 Q3 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	39599	40.74
T-Mobile NL	31740	32.66
Vodafone NL	25856	26.60
Sum	97195	100.00

Areas where T-Mobile announced 4G coverage in Q3 2015:

July: Heerenveen, Weststellingwerf, Hoogeveen, Meppel, Staphorst, Asten, Boekel, Deurne, Someren, Venray, Gemert-Bakel, Heeze-Leende, De Wolden, Westerveld and Midden-Drenthe

August: Leeuwarden, Graft-De Rijp, Beemster, Bergen (NH.), Castricum, Edam-Volendam, Enkhuizen, Heerhugowaard, Heiloo, Den Helder, Hoorn, Langedijk, Medemblik, Opmeer, Schagen, Texel, Schermer, Zeevang, Drechterland, Stede Broec, Waterland, Beesel, Nederweert, Venlo, Weert, Horst aan de Maas, Koggenland, Leudal, Cranendonck, Peel en Maas and Hollands Kroon

September: Emmen, Zeewolde, Skarsterlân, Lemsterland, Kampen, Noordoostpolder, Urk, Elburg, Oldebroek, Dronten, Baarle-Nassau, Etten-Leur, Rucphen, Steenbergen, Woensdrecht, Zundert, Halderberge, Roosendaal, Steenwijkerland, Alphen-Chaam and Zwartewaterland

All other cities in the TMNL coverage area had 4G enabled prior to Q3 2015.

Naturally, in the cities where 4G was announced in Q3, almost all of T-Mobile's 4G speedtests occur after announcing to customers that 4G is activated, so July, August or September 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 Q3/2015. 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 102256 - 5061 = 97195 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 11 cases, for Vodafone we removed 3 cases and for KPN we removed 7 cases, because they where above 150(or 225) MBps.

After removing in total 21 of these suspicious measurements, the data set contains 97174 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 35 cases, for Vodafone we removed 33 cases and for KPN we removed 62 cases.

After removing in total 130 of these suspicious measurements the data set contains 97044 speed tests at this point.

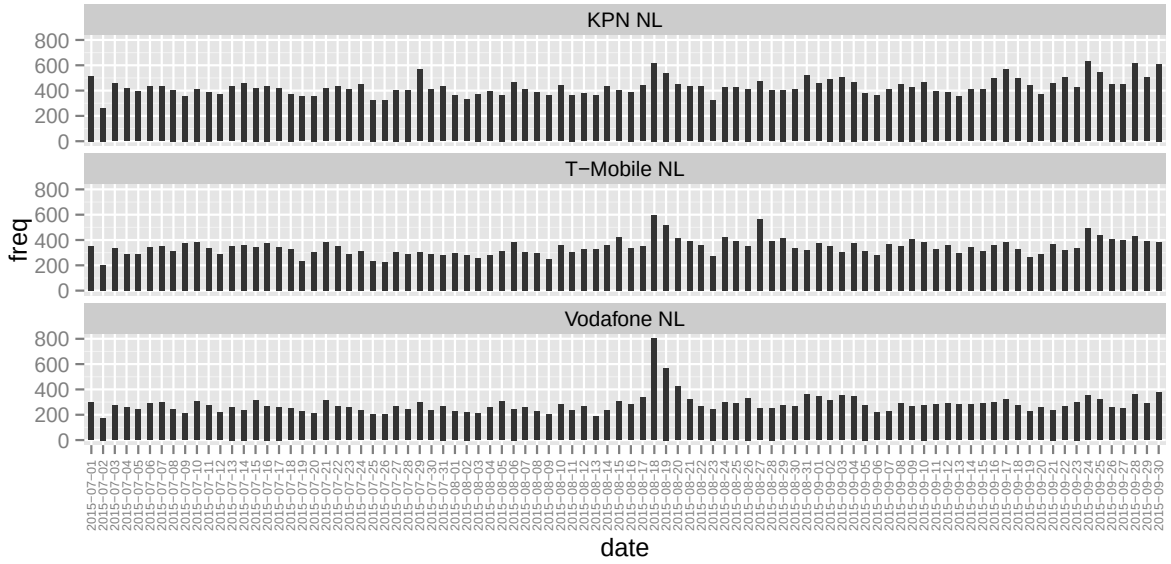
Let's look at **latency** also. We see the maximum value in latecy measurements is 65535, which is the maximum value for a variable of type unsigned short. This is clearly an outlier and should be removed.

Response Ookla: *"That issue was resolved in the latest Android release. As more and more clients download the latest version of the app, this will become less and less obvious. Just filter out for now until its cleaned up in the files."*

So we remove 4 measurements from the T-Mobile set , 5 measurements from the KPN set and 0 measurements from the Vodafone set. After this the data set contains 97035 speed tests at this point.

4.6.4 Suspicious dates or times

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



We find no disturbing or unknown peaks on a specific date, except for Vodafone on the 18/08/2015. This can be explained by the network incident that Vodafone had on this date, causing customers to experience slow or no internet. The problem was fixed the same day and it was communicated to customers, which is a stimulus to test.

Table 7: Counts per operator per month

	07 juli	08 augustus	09 september	Sum
KPN NL	12663	12907	13955	39525
T-Mobile NL	9774	11175	10741	31690
Vodafone NL	7895	9206	8719	25820
Sum	30332	33288	33415	97035

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 August and September, 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. This also enables them to activate LTE Advanced on those locations, which has an additional 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

	07 juli	08 augustus	09 september
KPN NL	32171.9	32089.7	35748.1
T-Mobile NL	42315.8	42262.6	41078.1
Vodafone NL	29682.1	28933.5	29970.1

Table below shows details for upload speed.

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

	07 juli	08 augustus	09 september
KPN NL	13693.1	13759.4	15061.9
T-Mobile NL	17487.2	17458.4	17558.1
Vodafone NL	13996.4	13614.7	14543.8

Table below shows details for latency.

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

	07 juli	08 augustus	09 september
KPN NL	43.1	42.7	39.7
T-Mobile NL	38.3	37.8	33.8
Vodafone NL	47.1	47.2	42.6

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 Q3 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.

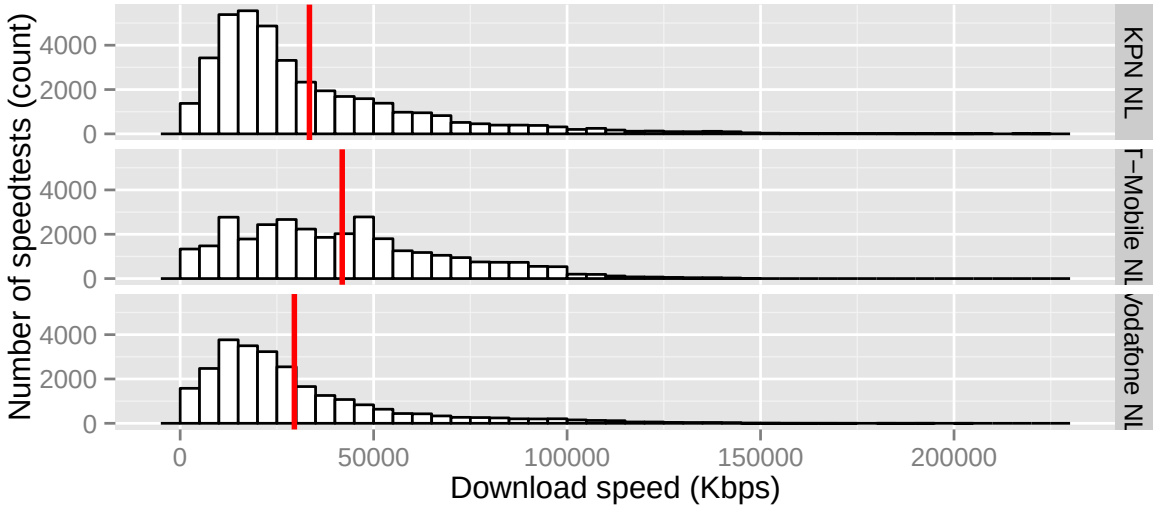
So how are the different metrics distributed?

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

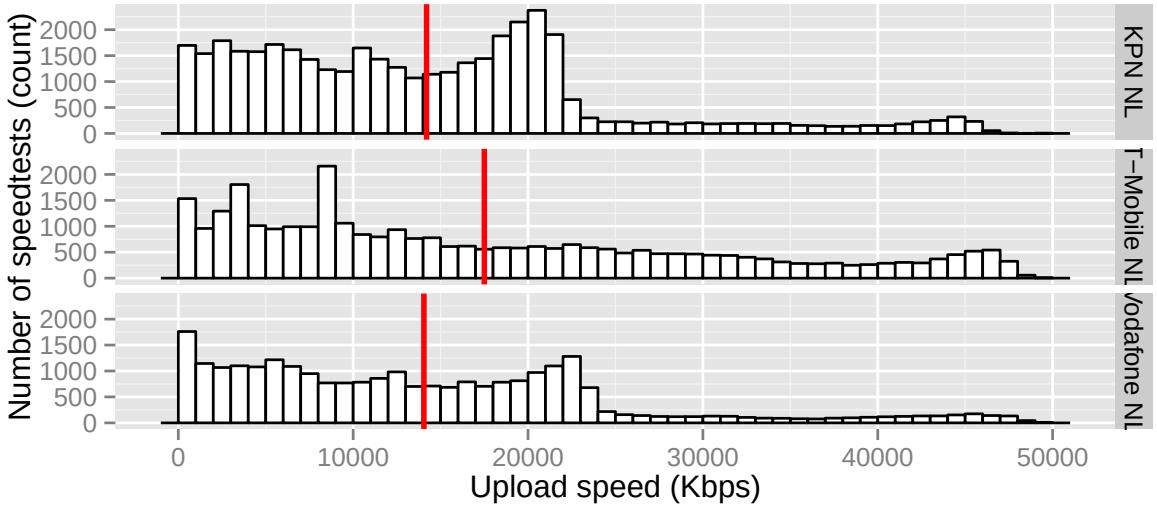
In the histogram below we see download speed in Kbps on the horizontal axis. The number of test cases are plotted as bars, on the vertical axis we see the count of the number of speed tests in a specific bin (or range). The histogram gives a visual representation of the distribution of the data.



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

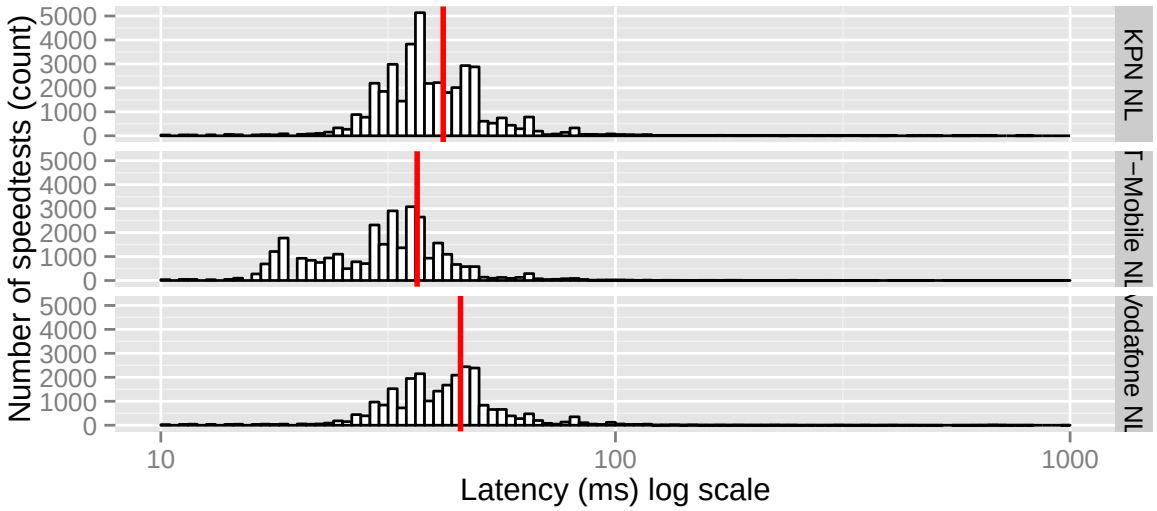
In the histogram below we see upload speed in Kbps on the horizontal axis. The number of test cases are plotted as bars, on the vertical axis we see the count of the number of speed tests in a specific bin (or range). The histogram gives a visual representation of the distribution of the data.



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 latency speed on the horizontal axis on a logaritmic scale. The log transformation makes the figure more readable. 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.



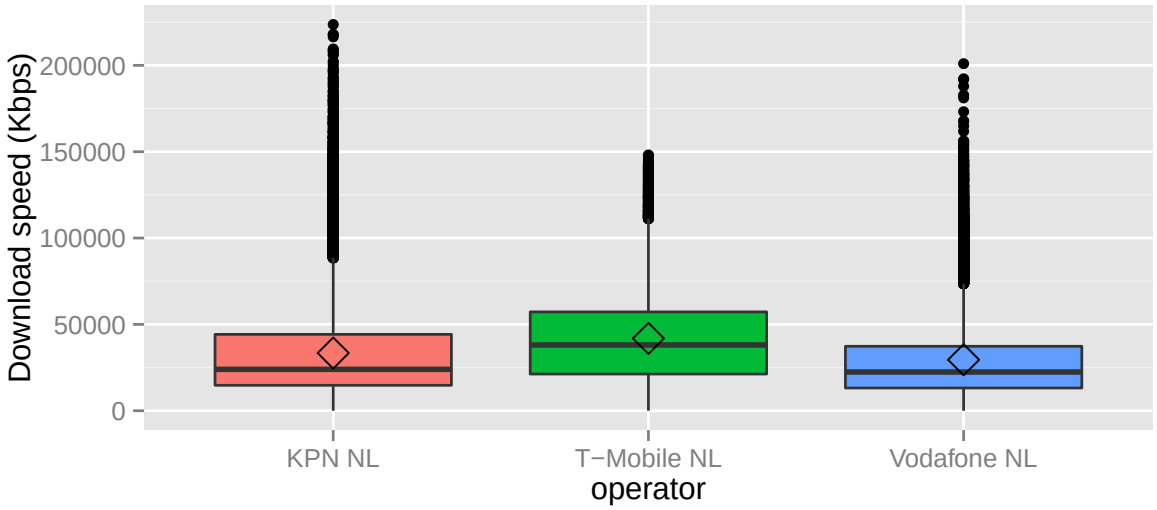
For latency smaller is better, so in this plot we are looking at which operator has the smallest latency. Again we see the red lines per operator. The average latency(red line) for T-Mobile is the most to the left, which means T-Mobile has the smallest average latency of the three operators.

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)

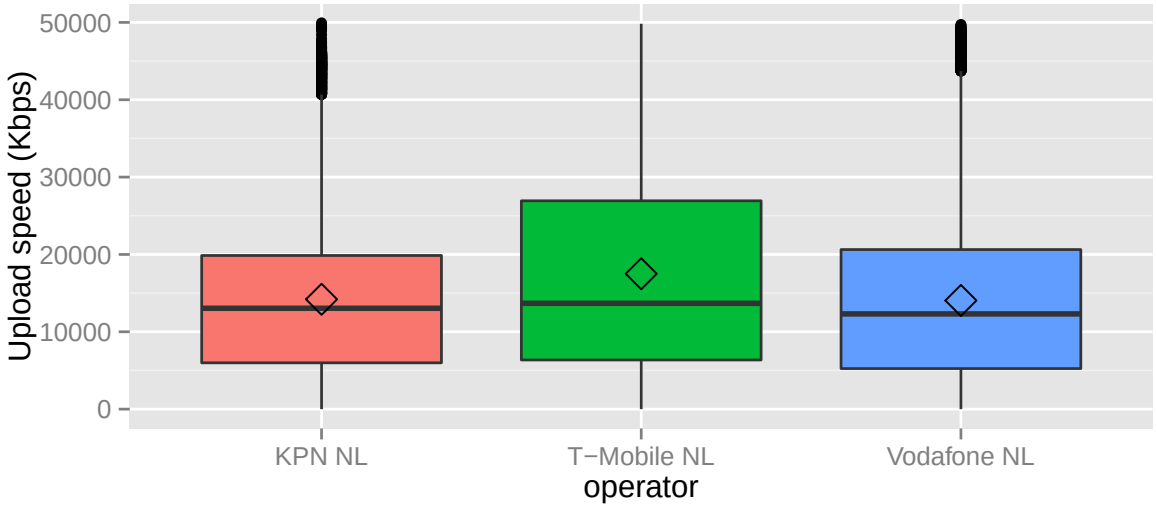
operator	10%	5%	1%
KPN NL	69698	92459	135121
T-Mobile NL	81151	92810	113986
Vodafone NL	62579	85027	117379

From the table we see that T-Mobile scores best in the 10% of download speed tests per operator. For the 5% percentile the T-Mobile outcome is very close to the KPN outcome but both better then Vodafone.

In the top 1% of download speed tests KPN scores best, followed by Vodafone. 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)

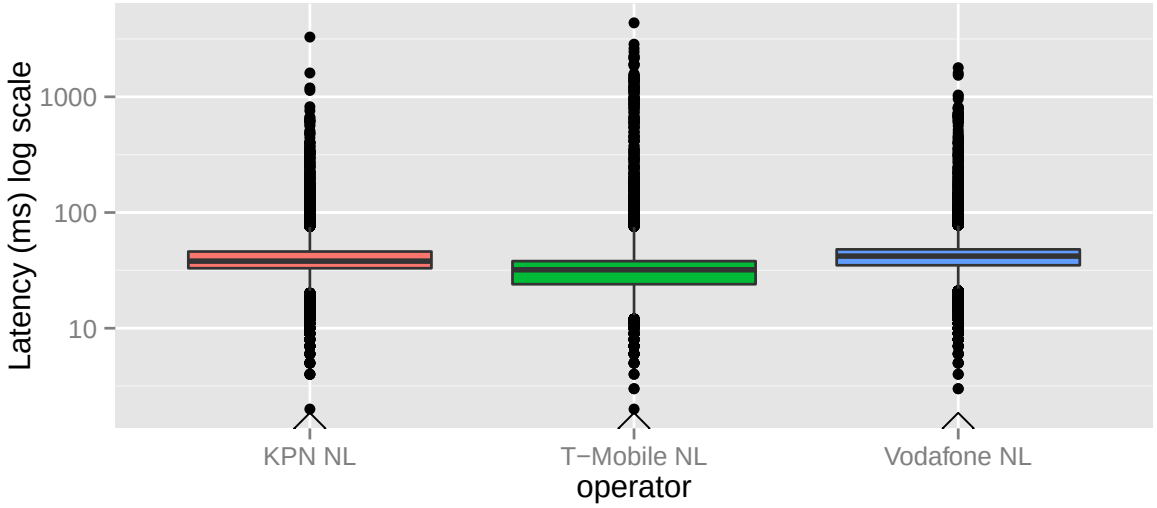
operator	10%	5%	1%
KPN NL	25796	36184	44699
T-Mobile NL	39964	44745	47188
Vodafone NL	26429	38827	46511

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.

If we look at the fastest 1%, 5% and 10% percentiles we see the following table:

Table 13: Top percentiles average latency (ms)

operator	1%	5%	10%
KPN NL	17	27	29
T-Mobile NL	15	18	19
Vodafone NL	15	27	30

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 97035 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	31690	41878	39525	33408	< 2.22e-16	Yes	8469.8	+/- 529	25.4
T-Mobile	Vodafone	31690	41878	25820	29512	< 2.22e-16	Yes	12365.1	+/- 556.2	41.9

Table 14: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	31690	17501	39525	14198	< 2.22e-16	Yes	3303	+/- 236.5	23.3
T-Mobile	Vodafone	31690	17501	25820	14045	< 2.22e-16	Yes	3455.9	+/- 263.2	24.6

Table 15: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	31690	36.6	39525	41.8	< 2.22e-16	Yes	-5.2	+/- 1.1	-12.4
T-Mobile	Vodafone	31690	36.6	25820	45.6	< 2.22e-16	Yes	-9	+/- 1.2	-19.7

Table 16: 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 8.47 Mbps, which is 25.4%. Also, from the data analysed in the investigated area the average download speed of the 4G network of T-Mobile outperforms Vodafone by 12.37 Mbps, which is 41.9%. 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.

code	naam	aantal inwoners	oppervlak(km^2)
GM0363	Amsterdam	810935	165.89
GM0599	Rotterdam	618355	208.88
GM0518	's-Gravenhage	508940	81.87
GM0344	Utrecht	328165	94.26
GM0772	Eindhoven	220920	87.67
GM0855	Tilburg	210270	117.24
GM0014	Groningen	198315	78.27
GM0034	Almere	196010	129.30
GM0758	Breda	179620	126.05
GM0268	Nijmegen	168290	53.61
GM0153	Enschede	158585	140.99
GM0200	Apeldoorn	157545	339.88
GM0392	Haarlem	155145	29.22
GM0307	Amersfoort	150895	62.82
GM0202	Arnhem	150820	97.96
GM0479	Zaanstad	150595	73.92
GM0394	Haarlemmermeer	144060	178.68
GM0796	's-Hertogenbosch	143730	84.40
GM0637	Zoetermeer	123560	34.53
GM0193	Zwolle	123160	111.31
GM0935	Maastricht	122485	56.62

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 21 cities looks like this.

From the CBS data we learn that the top 21 cities cover 5020400 out of 16828900 inhabitants. Which is 29.83 %. In terms of area this is 2353 km^2 of a total of 41545 km^2, which is 5.66%.

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	4541	41852	2332	39789	0.011489	No	2062.4	+/- 2101.9	NA
T-Mobile	Vodafone	4541	41852	2437	39074	8.7035e-05	Yes	2777.9	+/- 1822.6	7.1

Table 18: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	4541	18688	2332	15688	< 2.22e-16	Yes	3000.8	+/- 833.4	19.1
T-Mobile	Vodafone	4541	18688	2437	17735	0.0047396	Yes	953.6	+/- 869.7	5.4

Table 19: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	4541	34.3	2332	41.8	1.1775e-07	Yes	-7.4	+/- 3.6	-17.7
T-Mobile	Vodafone	4541	34.3	2437	42.1	3.2969e-08	Yes	-7.8	+/- 3.6	-18.5

Table 20: 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	1845	40350	1786	48123	7.2602e-14	Yes	-7772.9	+/- 2665.6	-19.3
T-Mobile	Vodafone	1845	40350	1220	41619	0.24484	No	-1268.7	+/- 2811.6	NA

Table 21: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	1845	19639	1786	18549	0.012725	No	1090	+/- 1127	NA
T-Mobile	Vodafone	1845	19639	1220	17964	0.00095449	Yes	1675.1	+/- 1305.5	9.3

Table 22: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	1845	33.3	1786	39.4	1.0665e-09	Yes	-6.1	+/- 2.6	-15.5
T-Mobile	Vodafone	1845	33.3	1220	43.6	< 2.22e-16	Yes	-10.3	+/- 3.1	-23.6

Table 23: 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	2189	40146	1630	39378	0.40538	No	768.6	+/- 2380.5	NA
T-Mobile	Vodafone	2189	40146	965	33527	1.2253e-10	Yes	6619.6	+/- 2636.4	19.7

Table 24: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	2189	20359	1630	17595	9.9484e-11	Yes	2763.6	+/- 1098.1	15.7
T-Mobile	Vodafone	2189	20359	965	14884	< 2.22e-16	Yes	5474.9	+/- 1282.8	36.8

Table 25: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	2189	35.4	1630	40.9	0.00086262	Yes	-5.5	+/- 4.2	-13.4
T-Mobile	Vodafone	2189	35.4	965	49.4	1.3342e-12	Yes	-13.9	+/- 5	-28.1

Table 26: 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	834	38923	1033	40794	0.18653	No	-1870.4	+/- 3649.7	NA
T-Mobile	Vodafone	834	38923	849	35268	0.0053994	Yes	3655.8	+/- 3384	10.4

Table 27: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	834	16853	1033	16926	0.89592	No	-73	+/- 1439.2	NA
T-Mobile	Vodafone	834	16853	849	15888	0.10941	No	965.2	+/- 1554	NA

Table 28: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	834	42.9	1033	41.3	0.72156	No	1.6	+/- 11.6	NA
T-Mobile	Vodafone	834	42.9	849	42.2	0.87213	No	0.7	+/- 11.5	NA

Table 29: 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	647	45718	934	51300	0.00032797	Yes	-5582.6	+/- 3999.2	-12.2
T-Mobile	Vodafone	647	45718	631	35104	4.0538e-12	Yes	10613.1	+/- 3908.7	30.2

Table 30: 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	20386	934	19405	0.1574	No	981.2	+/- 1789.1	NA
T-Mobile	Vodafone	647	20386	631	16103	1.0857e-09	Yes	4282.5	+/- 1798.2	26.6

Table 31: 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	44.7	934	42.3	0.63224	No	2.3	+/- 12.7	NA
T-Mobile	Vodafone	647	44.7	631	44.5	0.97478	No	0.2	+/- 12.7	NA

Table 32: 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	468	41630	445	40582	0.59427	No	1047.6	+/- 5075.9	NA
T-Mobile	Vodafone	468	41630	352	30235	1.1768e-09	Yes	11394.4	+/- 4773.6	37.7

Table 33: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	468	17526	445	15673	0.023148	No	1852.5	+/- 2102	NA
T-Mobile	Vodafone	468	17526	352	14090	5.5872e-05	Yes	3435.8	+/- 2189.8	24.4

Table 34: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	468	37.2	445	43.5	0.0086167	Yes	-6.2	+/- 6.1	-14.3
T-Mobile	Vodafone	468	37.2	352	44	0.0028955	Yes	-6.8	+/- 5.9	-15.5

Table 35: 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	384	45344	831	49124	0.047627	No	-3780.2	+/- 4919.6	NA
T-Mobile	Vodafone	384	45344	456	28684	< 2.22e-16	Yes	16659.7	+/- 4966.8	58.1

Table 36: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	384	17647	831	18643	0.21723	No	-996.3	+/- 2083.7	NA
T-Mobile	Vodafone	384	17647	456	14093	2.4844e-05	Yes	3554.4	+/- 2162.9	25.2

Table 37: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	384	45.3	831	39.2	0.29653	No	6.2	+/- 15.3	NA
T-Mobile	Vodafone	384	45.3	456	48.7	0.57308	No	-3.4	+/- 15.5	NA

Table 38: 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.

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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	400	42471	547	39494	0.13018	No	2976.9	+/- 5072.7	NA
T-Mobile	Vodafone	400	42471	331	23145	< 2.22e-16	Yes	19325.6	+/- 4147.3	83.5

Table 39: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	400	16749	547	14863	0.020244	No	1886.5	+/- 2093.7	NA
T-Mobile	Vodafone	400	16749	331	11412	1.801e-10	Yes	5337.1	+/- 2130.1	46.8

Table 40: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	400	33.8	547	40.3	0.029834	No	-6.5	+/- 7.8	NA
T-Mobile	Vodafone	400	33.8	331	45.3	0.00022966	Yes	-11.5	+/- 8	-25.4

Table 41: 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	373	38843	415	31444	8.6577e-06	Yes	7399	+/- 4266.1	23.5
T-Mobile	Vodafone	373	38843	294	29768	1.7866e-06	Yes	9075.5	+/- 4862.6	30.5

Table 42: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	373	16909	415	13415	1.9089e-05	Yes	3493.5	+/- 2095.4	26
T-Mobile	Vodafone	373	16909	294	14384	0.0067426	Yes	2524.8	+/- 2399.8	17.6

Table 43: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	373	51.5	415	44	0.52871	No	7.5	+/- 30.7	NA
T-Mobile	Vodafone	373	51.5	294	46	0.64635	No	5.4	+/- 30.6	NA

Table 44: 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.

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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	309	41077	599	35553	0.007439	Yes	5523.8	+/- 5315	15.5
T-Mobile	Vodafone	309	41077	305	28694	9.16e-08	Yes	12382.5	+/- 5916.3	43.2

Table 45: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	309	17491	599	15827	0.074565	No	1663.8	+/- 2407.2	NA
T-Mobile	Vodafone	309	17491	305	13805	0.00024274	Yes	3686.2	+/- 2579.7	26.7

Table 46: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	309	38.6	599	43.7	0.43573	No	-5	+/- 16.7	NA
T-Mobile	Vodafone	309	38.6	305	43.5	0.45117	No	-4.9	+/- 16.7	NA

Table 47: 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	330	38398	504	45017	0.001861	Yes	-6618.7	+/- 5474.1	-17.2
T-Mobile	Vodafone	330	38398	224	23802	< 2.22e-16	Yes	14596.6	+/- 4419.3	61.3

Table 48: 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	16536	504	17304	0.37359	No	-768.6	+/- 2230	NA
T-Mobile	Vodafone	330	16536	224	13427	0.0013503	Yes	3108.4	+/- 2493.9	23.1

Table 49: 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	37.3	504	42.1	0.07578	No	-4.8	+/- 7	NA
T-Mobile	Vodafone	330	37.3	224	50.6	0.10734	No	-13.2	+/- 21.2	NA

Table 50: 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	284	46905	673	38032	2.231e-05	Yes	8873.1	+/- 5367.8	23.3
T-Mobile	Vodafone	284	46905	279	31712	7.2824e-11	Yes	15192.7	+/- 5910.9	47.9

Table 51: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	284	18407	673	14712	6.946e-05	Yes	3695.3	+/- 2379.8	25.1
T-Mobile	Vodafone	284	18407	279	13055	3.1758e-07	Yes	5351.7	+/- 2671.2	41

Table 52: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	284	33.9	673	44.8	0.00018344	Yes	-10.9	+/- 7.5	-24.3
T-Mobile	Vodafone	284	33.9	279	45.8	0.00081078	Yes	-11.8	+/- 9.1	-25.8

Table 53: 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	399	44050	310	36116	0.00041186	Yes	7934.2	+/- 5771.1	22
T-Mobile	Vodafone	399	44050	312	26661	< 2.22e-16	Yes	17388.9	+/- 5037.5	65.2

Table 54: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	399	20863	310	13732	2.3733e-13	Yes	7131.1	+/- 2465.3	51.9
T-Mobile	Vodafone	399	20863	312	11595	< 2.22e-16	Yes	9267.9	+/- 2442.3	79.9

Table 55: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	399	41.8	310	37.5	0.51334	No	4.3	+/- 16.8	NA
T-Mobile	Vodafone	399	41.8	312	39.3	0.70026	No	2.5	+/- 16.8	NA

Table 56: 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	285	38894	468	24258	6.2876e-15	Yes	14635.8	+/- 4717.5	60.3
T-Mobile	Vodafone	285	38894	295	34740	0.06598	No	4154	+/- 5828.2	NA

Table 57: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	285	14180	468	14967	0.30887	No	-786.5	+/- 1995.9	NA
T-Mobile	Vodafone	285	14180	295	14827	0.46598	No	-646.7	+/- 2290.9	NA

Table 58: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	285	41.5	468	40.5	0.74477	No	1	+/- 8.2	NA
T-Mobile	Vodafone	285	41.5	295	41.9	0.90489	No	-0.4	+/- 8.7	NA

Table 59: 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	513	42087	539	37721	0.015303	No	4366.1	+/- 4638.3	NA
T-Mobile	Vodafone	513	42087	309	28911	4.5752e-12	Yes	13175.6	+/- 4828.4	45.6

Table 60: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	513	19118	539	16320	0.00021898	Yes	2797.5	+/- 1945.9	17.1
T-Mobile	Vodafone	513	19118	309	12597	1.5539e-14	Yes	6520.8	+/- 2150.3	51.8

Table 61: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	513	37.7	539	39.1	0.79539	No	-1.4	+/- 14.4	NA
T-Mobile	Vodafone	513	37.7	309	41.3	0.51825	No	-3.6	+/- 14.4	NA

Table 62: 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	300	46343	389	50239	0.13546	No	-3896.3	+/- 6733.3	NA
T-Mobile	Vodafone	300	46343	228	29863	6.6098e-11	Yes	16479.4	+/- 6385.9	55.2

Table 63: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	300	18966	389	17121	0.068476	No	1845	+/- 2612.1	NA
T-Mobile	Vodafone	300	18966	228	14625	5.0837e-05	Yes	4340.6	+/- 2746.6	29.7

Table 64: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	300	33.1	389	39.6	0.011674	No	-6.5	+/- 6.6	NA
T-Mobile	Vodafone	300	33.1	228	39	0.015463	No	-5.9	+/- 6.3	NA

Table 65: 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.

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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	643	37819	668	33435	0.0019843	Yes	4384.3	+/- 3649.6	13.1
T-Mobile	Vodafone	643	37819	507	33038	0.0028777	Yes	4781	+/- 4129.4	14.5

Table 66: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	643	18052	668	15048	1.3972e-05	Yes	3003.9	+/- 1776.6	20
T-Mobile	Vodafone	643	18052	507	14915	1.6399e-05	Yes	3137.4	+/- 1870.6	21

Table 67: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	643	35.9	668	42.8	0.014813	No	-6.9	+/- 7.3	NA
T-Mobile	Vodafone	643	35.9	507	48	0.00018753	Yes	-12.1	+/- 8.3	-25.2

Table 68: 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	341	41447	428	40895	0.80116	No	552.3	+/- 5661.6	NA
T-Mobile	Vodafone	341	41447	333	34930	0.0037256	Yes	6517.7	+/- 5784.2	18.7

Table 69: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	341	16088	428	16040	0.95403	No	48.4	+/- 2166.7	NA
T-Mobile	Vodafone	341	16088	333	12874	0.00020028	Yes	3214.3	+/- 2219.7	25

Table 70: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	341	46.5	428	42.1	0.40336	No	4.3	+/- 13.4	NA
T-Mobile	Vodafone	341	46.5	333	45.6	0.86187	No	0.9	+/- 13.4	NA

Table 71: 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.

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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.

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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	391	40092	401	34781	0.0034505	Yes	5311.7	+/- 4675.6	15.3
T-Mobile	Vodafone	391	40092	249	32211	0.00040427	Yes	7881.4	+/- 5720	24.5

Table 72: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	391	18267	401	15261	0.00026166	Yes	3005.8	+/- 2116	19.7
T-Mobile	Vodafone	391	18267	249	12561	6.5808e-09	Yes	5705.8	+/- 2504.2	45.4

Table 73: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	391	33	401	40.5	0.0024517	Yes	-7.5	+/- 6.4	-18.5
T-Mobile	Vodafone	391	33	249	51.5	6.3947e-09	Yes	-18.5	+/- 8.1	-35.9

Table 74: 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	262	43224	424	30162	4.1998e-09	Yes	13062.7	+/- 5642.6	43.3
T-Mobile	Vodafone	262	43224	274	27236	2.6972e-13	Yes	15988.2	+/- 5479.7	58.7

Table 75: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	262	16257	424	13789	0.0089638	Yes	2467.6	+/- 2431.8	17.9
T-Mobile	Vodafone	262	16257	274	14410	0.070225	No	1846.4	+/- 2631.3	NA

Table 76: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	262	34.7	424	41	7.0096e-08	Yes	-6.3	+/- 3	-15.4
T-Mobile	Vodafone	262	34.7	274	45	1.849e-11	Yes	-10.3	+/- 3.9	-22.9

Table 77: 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	219	40525	214	35440	0.047859	No	5084.6	+/- 6629.8	NA
T-Mobile	Vodafone	219	40525	577	31166	9.3139e-06	Yes	9358.6	+/- 5394	30

Table 78: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	219	17492	214	16354	0.31502	No	1138.2	+/- 2927.5	NA
T-Mobile	Vodafone	219	17492	577	15745	0.064254	No	1747.5	+/- 2438.3	NA

Table 79: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	219	39.1	214	48	1.7453e-14	Yes	-8.9	+/- 2.9	-18.5
T-Mobile	Vodafone	219	39.1	577	61.8	3.7937e-08	Yes	-22.7	+/- 10.5	-36.7

Table 80: 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	7461	44715	14828	35141	< 2.22e-16	Yes	9573.2	+/- 1018.4	27.2
T-Mobile	Vodafone	7461	44715	9180	28259	< 2.22e-16	Yes	16456	+/- 1053.2	58.2

Table 81: Comparison of means for metric: Download (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(Kbps)	Conf Int	Rel(%)
T-Mobile	KPN	7461	17289	14828	14143	< 2.22e-16	Yes	3145.5	+/- 457.4	22.2
T-Mobile	Vodafone	7461	17289	9180	13967	< 2.22e-16	Yes	3322	+/- 502.6	23.8

Table 82: Comparison of means for metric: Upload (Kbps)

Operator1	Operator2	Sample1	Mean1	Sample2	Mean2	P-value	Sign.	Diff(ms)	Conf Int	Rel(%)
T-Mobile	KPN	7461	36.3	14828	39.7	2.8795e-05	Yes	-3.4	+/- 2.1	-8.6
T-Mobile	Vodafone	7461	36.3	9180	43.6	< 2.22e-16	Yes	-7.4	+/- 2.1	-17

Table 83: 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.

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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.

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