

Digital Forensics Report for Dagens Næringsliv

Norwegian University of Science and Technology

10th April 2018

Executive summary

Dagens Næringsliv (DN) approached the Norwegian University of Science and Technology (NTNU) to investigate whether some data manipulation had occurred in various log files in its possession. DN advised they are in the process of investigating what it suspected to be the fraudulent manipulation of data in the database of a music streaming service and sought cross-validation on this hypothesis.

The NTNU was asked to investigate whether there was in fact manipulation of the data, and if so, the scope, methodology, and location of this manipulation. DN suspected there had been manipulation of data due to a spike of user records within specific time periods, but did not provide any further details as to why they determined the data to be manipulated and the methods by which it occurred.

Using advanced statistical analysis of the data provided by DN, NTNU determined that there had in fact been a manipulation of the data at particular times due to the large presence of similar duplicate records occurring for a large percentage of the userbase that was active at any given time. In reviewing the data, in isolation from any other records or logs, it was not possible to determine the exact means of manipulation; however, the absence of records with unreadable data suggested it was not an external Structured Query Language Injection (SQLi) vector based attack, but rather manipulation from within the streaming service itself. Due to the targeted nature and extent of the manipulation, it is very unlikely that this manipulation was solely the result of a code based bug or other system anomaly.

The following analysis shows in detail why this conclusion is the most likely conclusion and further, the nature and extent it is suspected that the manipulation has affected the accuracy of the data.

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1 Hypothesis

DN suspect the data it has provided us, is evidence of data manipulation within the records database of a popular music streaming service. DN suspects that this evidence shows an intent by parties within the music streaming service to boost royalty payments and/or dress up the music streaming service as more profitable than it is in reality. DN has asked us to analyse the data and determine:

1. if there has been manipulation of the data;
2. the method of the data manipulation;
3. the affected users and numbers thereof;
4. the affected tracks and numbers thereof;
5. the affected artists and numbers thereof; and
6. where possible the difference between actual intentional plays and manipulated plays.

2 Assumptions

In order to provide a reproducible and reputable finding, it is important that we state our assumptions on which our findings and analysis is based. In preparing this report, we assume:

- the data was acquired legally;
- the data we have received is complete for the time periods provided;
- DN has not altered the data in any significant manner;
- DN has provided us the data in its original form;
- any manipulation of the data has either occurred at the server or users' end and not the subject of being altered in transit between both;
- the time provided by the client will be sufficient to determine whether any manipulation of the data has occurred;
- DN has been forthright and honest with us;
- DN is not using this report to discredit us, nor any of our affiliated organisations;
- DN is using this report for journalism and not for illegal or immoral purposes; and
- DN will fairly and accurately report our participation in this project.

We also assume, that any fundamental errors or mistakes that have existed in our understanding of the project and the requested report, will be addressed with us, and while be provided with time for the preparation of an amended report, outlining how these differences alter our opinion and why.

3 Data preparation

On February 7, 2018 we received the log files from DN. We first generated MD5 hash sums for each log file immediately after receiving it. These MD5 hashes were compiled into a list and shared via e-mail with DN for back up and cross-validation. The MD5 list was further used by us to preserve the integrity of our work, to always ensure that we worked with the original data. The complete hash list is provided in Appendix G.

The files were transferred from the external hard disk to our server via PuTTY Secure Copy Protocol (PSCP). PSCP is a command line tool for transferring files securely between computers using an Secure Shell (SSH) connection. The data was then rehashed to ensure we transferred the data successfully and in its entirety. Using this data, we performed our analysis as described in Section 4.

After the initial transfer described above, we copied the data to another part of the file system. This copy was reserved as a backup. Both the original and backup files were made read-only to ensure they remained unchanged and avoid unintentional deletion.

3.1 Data structuring

MySQL database tables for each log file were created and we populated each tables with the data contained within the corresponding log file. Listing 1 shows the MySQL query used to generate the tables used for the analysis. The table name is replaced with the respective date for each log file, while each field corresponds to a column found in the original CSV file.

Listing 1: Example of query to create database table for date 13.02.2016

```
CREATE TABLE IF NOT EXISTS new_period_2016_02_13 (  
  id INT UNSIGNED AUTO_INCREMENT PRIMARY KEY,  
  playdatetime DATETIME,  
  countrycode CHAR(2),  
  systemuserid INT UNSIGNED,  
  trackid INT UNSIGNED,  
  offlineplay CHAR(1)  
);
```

The content of each log file was loaded into their respective MySQL database table via the SQL command/query below. This command ignores the first row which contained headings for each column, and then inserts each row into the database without modification.

Listing 2: SQL query to load CSV file content into a database table

```
LOAD DATA LOCAL INFILE filepath INTO TABLE table FIELDS TERMINATED  
BY ';' LINES TERMINATED BY '\n' IGNORE 1 ROWS (playdatetime,  
countrycode, userid, trackid, offlineplay)
```

An example of the first ten rows for the CSV file *all_data_ny_log2016-02-13.csv* (MD5: EC3D06A81F12990BB0B04EAD9A153E57) is seen below. All files contained the same column names, separated by semicolons, with the labels *timestamp*, *countrycode*, *systemuserid*, *trackid* and *offlineplay*.

Listing 3: First ten rows for date 13.02.2016

```
timestamp;countrycode;systemuserid;trackid;offlineplay
0028-02-12 18:31:19.000;NO;13356188;20659857;Y
0028-02-12 20:25:54.000;NO;13866374;422113;Y
0028-02-12 22:51:47.000;NO;15380556;1647477;Y
0028-02-12 22:58:55.000;NO;15380556;6640790;Y
0028-02-12 23:03:43.000;NO;15380556;6640791;Y
0028-02-12 23:10:23.000;NO;15380556;6640784;Y
0028-02-13 00:19:50.000;NO;13356188;20659854;Y
0028-02-13 00:23:18.000;NO;13356188;20659855;Y
0028-02-13 00:37:23.000;NO;15380556;6640790;Y
```

The `timestamp` column takes has the format `YYYY-mm-dd HH:MM:SS.f`, where `mm` and `dd` are zero-padded two decimal number, and `f` is a zero-padded three decimal number for milliseconds. The `countrycode` is a two-letter country code, which is defined in the ISO 3166-1 alpha-2 standard. Both fields `systemuserid` and `trackid` is a decimal number of varying length; we suspect these numbers are unique numeric values that are incremented when a new user or track is created within the system and each number represents a distinct user or track. Finally, `offlineplay` holds one of two values: `N(o)` or `Y(es)` for whether the log entry is an online or offline record, respectively. All filed except for `timestamp` can be treated as *categorical* variables.

3.2 Data description

We received 74.1 GB in 65 CSV (Comma Separated Values) formatted files via an external hard disk. The files contain log entries allegedly representing streamed songs for a total of 65 days over a 110 day period, in two distinct periods of consecutive days. The first period is between 2016-01-21 and 2016-03-03 (43 days), while the second period is between 2016-04-18 and 2016-05-09 (22 days). These periods will frequently be referred to as “period 1” and “period 2”, respectively. We did not receive any logs for the intervening days, i.e. between 2016-03-04 and 2016-04-17. See Figure 1 for an overview.

There are 1,590,422,377 log entries in total. Figure 2 shows the number of entries per day. Figure 3 shows the percentage of online versus offline log entries; the total number of tracks played (Figure 4) and number of unique system users (Figure 5). Keep in mind there is a missing period left out from these figures.

We identified some anomalous timestamps in the data, for example 0028-02-12. Although it is impossible to have log entries from the year 28, they do not necessarily represent any tampering with the data. The reason for this is that devices playing music without a connection to the log server may use a system clock for a timestamp. Any devices without synchronisation to an external clock may produce an incorrect timestamp for offline playbacks. Another issue is less powerful devices may be incapable of logging in milliseconds, which causes the timestamp to end with “.000”. Online log entries have less issues as they likely use the log server’s time.

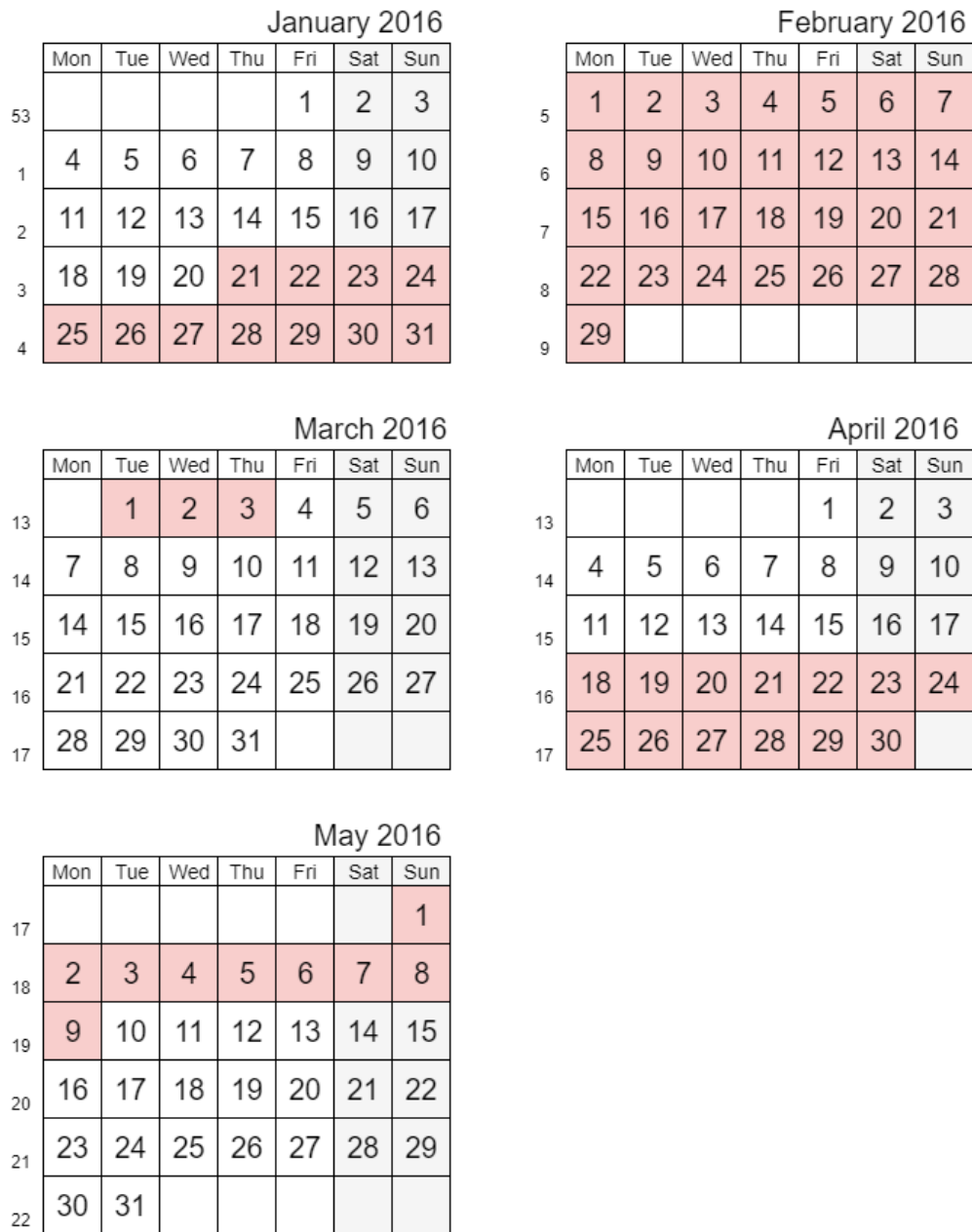


Figure 1: Highlighted days represent days with log files.

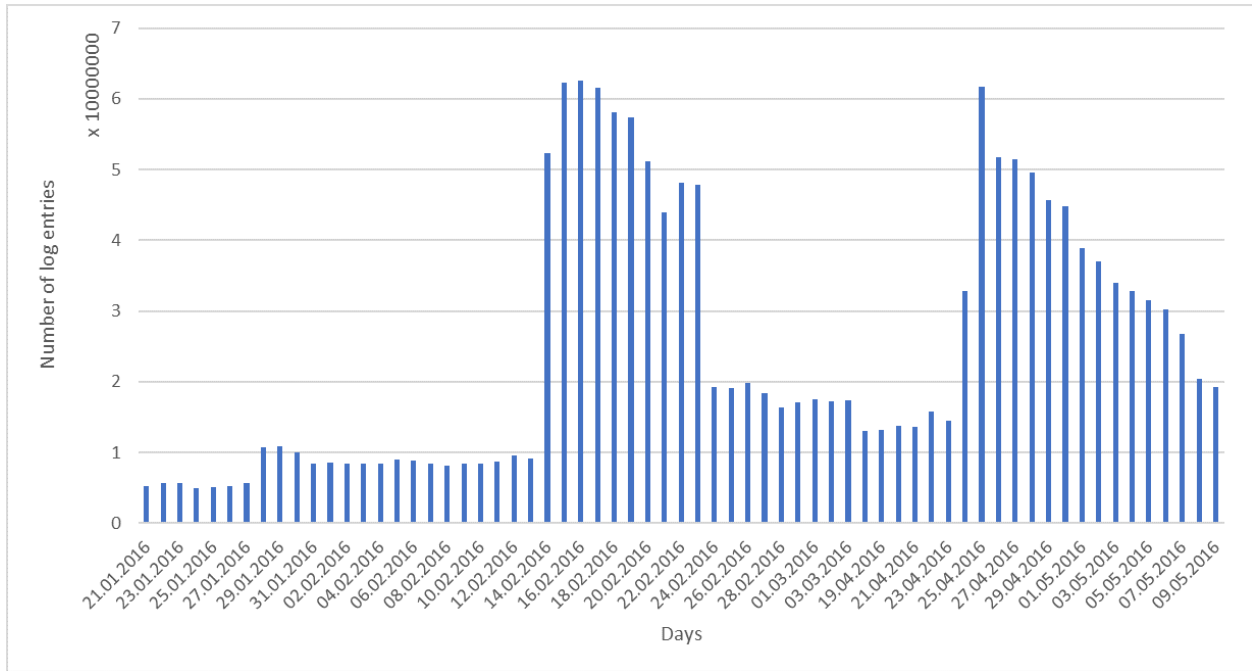


Figure 2: Number of log entries

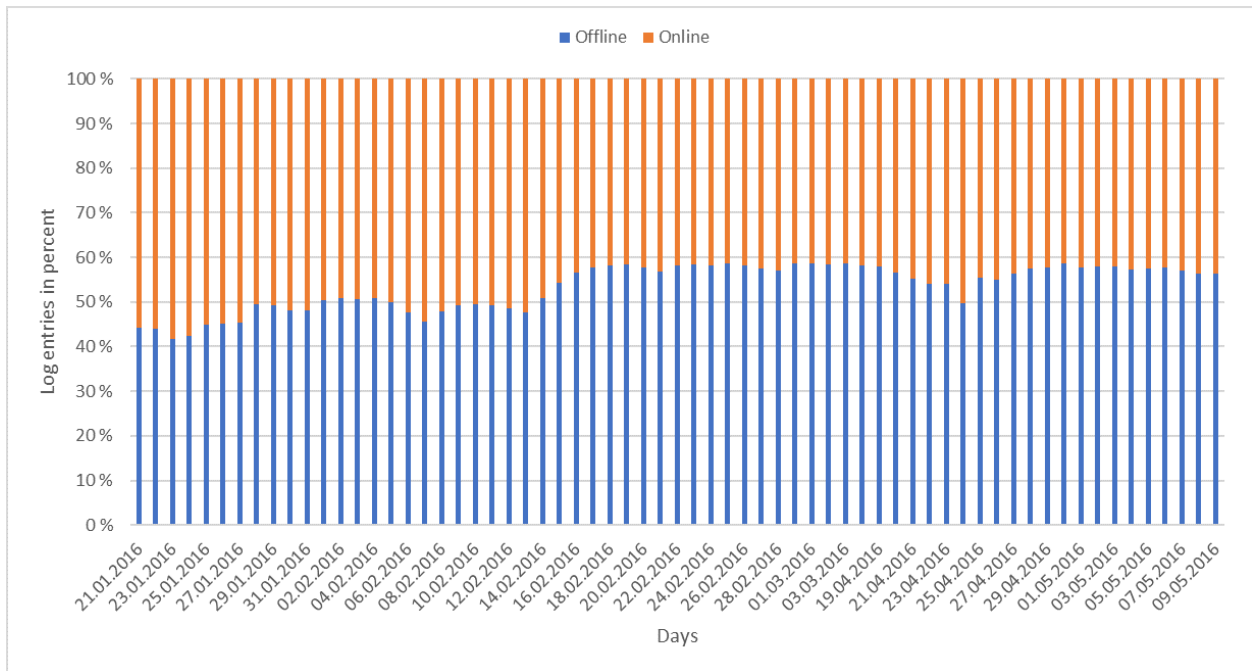


Figure 3: Online and offline playbacks

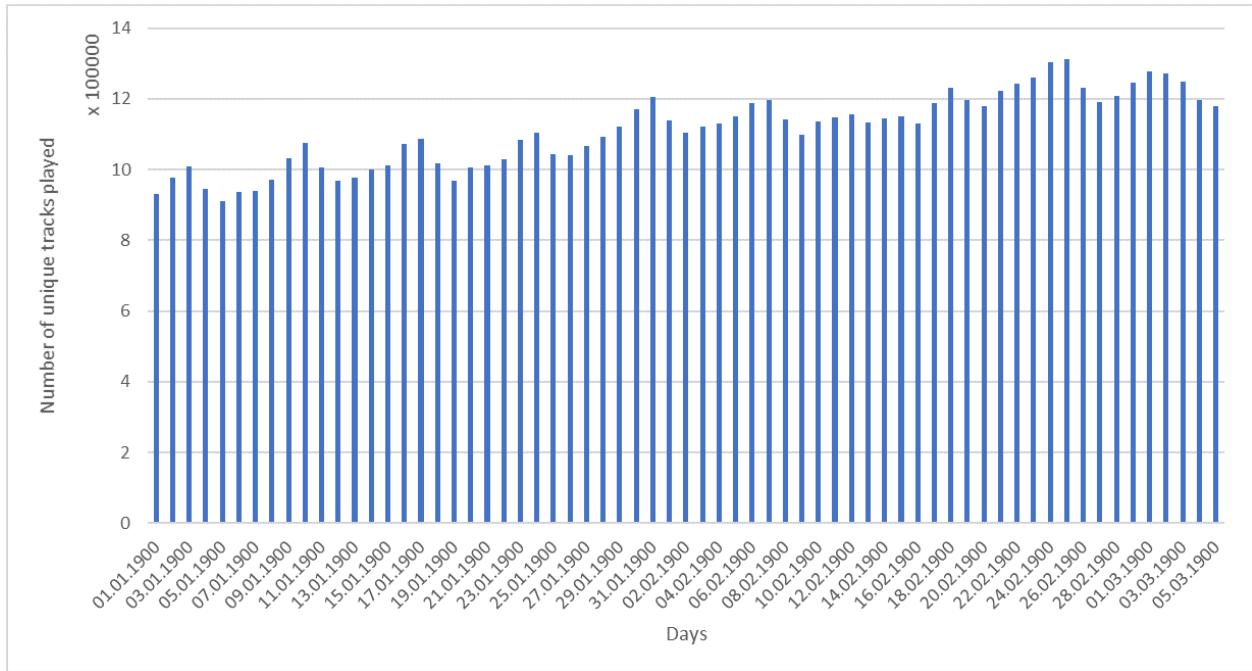


Figure 4: Number of unique tracks played

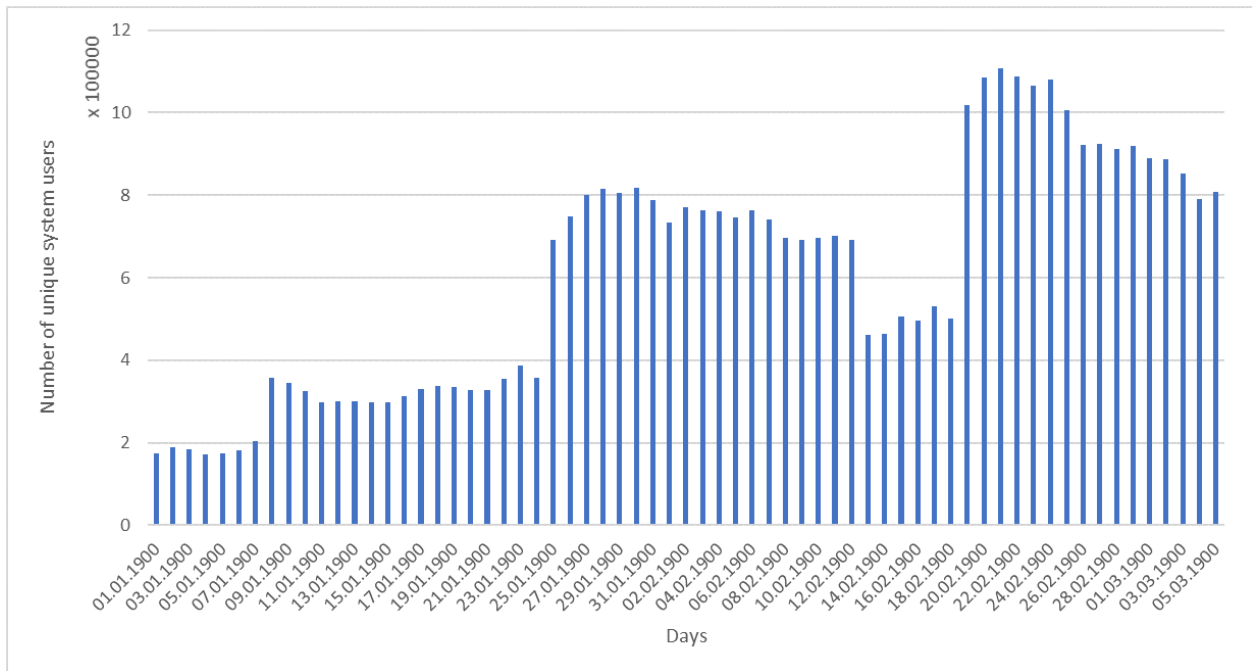


Figure 5: Number of unique system users

4 Methodology

We documented each step in analysing the data so our results may be reproduced. Each step has its own subsection to describe its purpose/objective, a description, pseudo code and expected results. Steps with several sub-goals are enumerated.

A common expectation is that many of our analysis results should follow Benford's law [1]. Benford's law is the mathematical theory of leading digits, that in data sets, the leading digits are distributed in a specific, nonuniform way [2]. For example, the number of people who have listened to five songs would be larger than people who have listened to fifty songs. In other words, lower numbers will appear first in a frequency distribution in many naturally cases, as seen in Figure 6. Benford's law is used in a variety of fields for the purposes of fraud detection [5, 3, 4].

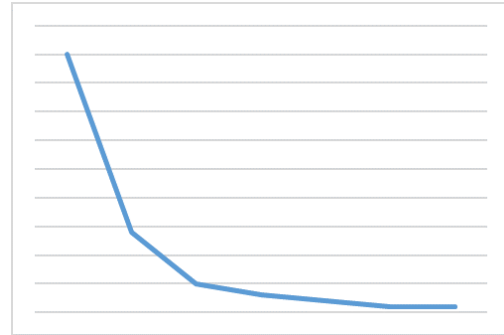


Figure 6: Benford's law example

4.1 Descriptive statistical analysis: Analysis method 1

Purpose, objective or hypothesis

The first step in analysing data is a descriptive statistical analysis to better understand the nature of the data we received. We ran several queries to find its dimensions, possible values and so forth.

Verbatim description of the analysis

1. For how many days have we received data? What kind of period does the data give us? Is there any inconsistencies between the filename and the data rows within the file?
2. How large is the data we received (i.e. how many rows)?
3. How many rows are for online and offline plays?
4. How many distinct tracks has been played?
5. How many distinct countries have it been played from?
6. How many distinct users has been playing each day?
7. What are the fields in the CSV file and what possible values can they take?

Pseudo code

1. Count the number of files to see how many days we have received, as each file contains data for one day. Then inspect the filename to determine the date and thus the period for which we have data. Finally, check whether the majority of the data rows within the files corresponds to the date found in the filename.
2. Query each DB table to count the number of rows: `SELECT COUNT(*) FROM table`.
3. Query each DB table to count the number of online and offline plays: `SELECT (SELECT COUNT(*) FROM table WHERE offlineplay LIKE 'Y') as offline, (SELECT COUNT(*) FROM table WHERE offlineplay LIKE 'N') as online`
4. Query each DB table to count the number of distinct tracks being played: `SELECT (SELECT COUNT(*) FROM (SELECT DISTINCT trackid FROM table) a) as utrack`
5. Query each DB table to count the distinct countries: `SELECT (SELECT COUNT(*) FROM (SELECT DISTINCT countrycode FROM table) a) as countrycode`
6. Query each DB table to count the distinct users: `SELECT (SELECT COUNT(*) FROM (SELECT DISTINCT systemuserid FROM table) a) as systemuserid`
7. Inspect the CSV header (first row in each file) to determine column names and then inspect a portion of the rows to determine possible values they can have.

Expected results

1. One number for how many files we have received, which should correspond to the number of days. The period is an ordered list of the files. When counting the timestamps found within the files, we expect to find a higher count for the respective date found in the filename. Any large count for other days can be due to user's inability to synchronise their system clocks or that the playbacks have been played on another date but was uploaded/registered for a particular day.
2. One number for how many rows (i.e. distinct playbacks) have been registered by the system on a particular day. In addition, the file size can also be used to get an impression for the received data.
3. Two numbers for the number of online and offline playbacks. We will get to understand the distribution between online and offline playbacks. We expect to find more online playbacks as this is a streaming service, however, a more even distribution would not necessarily be suspicious as it depends on the behaviour of their users. Our expectation is based on the idea of a streaming service is usually online and on-demand.
4. One number for how many distinct songs/tracks are found for each day. Expect that this number would be very even in relation to how many distinct users there are. Releases of new albums should have a low to no impact on this number, unless multiple new albums are released.

5. One number for distinct countries represented in the dataset. This number could be affected by services such as proxies or Virtual Private Networks (VPN), because of the region blocks on music playbacks. Expect to find countries particularly in Europe and North America.
6. One number for how many distinct system users are found for each day. Comparing this number for multiple days can show whether their customers have grown, shrinks or stays the same over a period.
7. A list with the names of each column found in the files. Inspecting multiple rows will give us an assumption of which possible values each column can have.

4.2 Logical impossibilities: Analysis method 2

Purpose, objective or hypothesis

In this method we attempted to find occurrences of logical impossibilities, such as identical or unequal tracks being played at the same time. The client also asked us to do this step, and extract the affected log entries so they could be analysed separately.

Verbatim description of the analysis

1. Find occurrences of two identical track IDs with the same timestamp for a system user ID
2. Find occurrences of more than two identical track IDs with the same timestamp for a system user ID
3. Find occurrences of two unequal track IDs with the same timestamp for a system user ID
4. Find occurrences of more than two unequal track IDs with the same timestamp for a system user ID

Pseudo code

1. See Appendix C
2. See Appendix C
3. See Appendix D and E
4. See Appendix D and E

Expected results

We do not expect to find a lot of occurrences of logical impossibilities, as they simply should not exist in the data. It should, for example, be impossible to find multiple distinct track IDs being played at the same time. An exception is that there may exist such logical impossibilities from systems with anomalous timestamps. However, this will be considered a limitation for those devices, rather than suspicious activity.

1. A file containing log entries with exactly two identical track IDs which are played at the same time by system user IDs
2. A file containing log entries with three or more identical track IDs which are played the same time by system user IDs
3. A file containing log entries with only two unequal track IDs which are played at the same time by system user IDs
4. A file containing log entries with three or more identical track IDs which are played at the same time by system user IDs

4.3 Unique tracks per user: Analysis method 3

Purpose, objective or hypothesis

Count the number of unique tracks played per user (`numuplays`), then count `numuplays` to find the frequency distribution of unique tracks being played. This finds how many X tracks has been played N times, for example: “436249 tracks have been played 2 times”. We try to identify unexpected N counts of played tracks. This step can also identify unusual high counts for played tracks that day, for example: “1 tracks have been played 300 times”. Then, we can look further into that particular track with a high play count.

Verbatim description of the analysis

Group based on `systemuserid` and `trackid`, and then `size()` to get the number of times `systemuserid` u_i have played track t_j . Group by and `sum()` this number (`numuplays`) to count how many times tracks have been played 1, 2, 3, 4, ... n times. Will result in an ordered set result, which looks like this: [1, 3225011], [2, 436249], [3, 113165], [4, 46112], [5, 21189], [6, 12215]. This is interpreted as “3 225 011 tracks have been played 1 time”, and so forth.

Pseudo code

```
1 df.groupby(['systemuserid', 'trackid']).size().to_frame('numuplays')
   .reset_index().groupby('numuplays').size().to_frame('count').
   reset_index()
```

Expected results

We would expect to see a lot of tracks being played once or just a few times, i.e. the frequency distribution follow Benford's law. We consider it suspicious when encountering large "bumps" in the curve.

4.4 Tracks per user: Analysis method 4

Purpose, objective or hypothesis

In this method of analysis, the number of tracks played per user is counted (`count`) and the sum of the count calculated. This is used to assess how many X users have played how many N tracks that day; for example "9778 users have played 1 tracks". This step can identify unusual or unexpected high counts of N , for example: "1 users have played 300 tracks". We can then look further into any users with such high music play counts. However, this is dependent on the final number, as it could just be a large music consumer.

Verbatim description of the analysis

Group based on `systemuserid` (can include grouping by `trackid` to count unique tracks), and then `size()` to get the number of times `systemuserid` u_i have played track t_j . Group by and `sum()` to get the total played tracks per `systemuserid`. Finally group by `count` and `size()` to group the number of counts and find how many users have played tracks 1, 2, 3, 4, ... n times. These steps will result in an ordered set result looking like this: $[1, 9778], [2, 7000], [3, 6115], [4, 5879], [5, 5672], [6, 5472]$. This is interpreted as "9778 users have played 1 track".

Pseudo code

```
1 df.groupby('systemuserid').size().to_frame('count').reset_index().
   groupby('count').size().to_frame('users').reset_index()
```

Expected results

It is expected that system users a more likely to play tracks a few times, thus have the frequency distribution follow Benford's law. Again, it would be suspicious if we encountered a conspicuous deviation from the curve anticipated by Benford's law.

4.5 Popular tracks: Analysis method 5

Purpose, objective or hypothesis

This analysis method was used to provide a further understanding of the most frequent tracks that was played each day. Comparing the results from different dates will also allow us to determine trend based changes such as when tracks move between being unpopular to popular, and vice versa.

Verbatim description of the analysis

In order to analyse the data as described, we grouped `trackid` and used `size()` to count how many times track t_j was played. This data was transferred frame called `frequency`, and sorted in descending numerical order (largest to smallest) by `frequency`.

Pseudo code

```
df.groupby('trackid').size().to_frame(name='frequency').  
sort_values(by='frequency', ascending=False)
```

Expected results

This will result in a list sorted according to how many times each track has been played. Each distinct playback of a song will count towards one in the frequency. An example of expected results: `[53960289, 12916]`, `[52901260, 12562]`, `[53893678, 11736]`, `[54511031, 9294]`, `[53893676, 6689]`. This list is interpreted as “Track with ID 53960289 has been played 12916 times today”.

4.6 Number of unique tracks: Analysis method 6

Purpose, objective or hypothesis

We then analysed how many users played a track at least once. The difference between this and analysis method 4 (Subsection 4.4) is here we look at distinct tracks being played by all users. While analysis method 4 is more general and looks at all tracks being played. We find that X users have been playing N unique/distinct tracks that day, for example: “11 794 users have played 1 distinct/unique tracks”. The aim of such an analysis is to assess for the presence of unexpected N counts of distinct/unique tracks played. This result can be used to further identify track IDs and system user IDs where this occurred.

Verbatim description of the analysis

In order to analyse the data in this way we counted the number of unique/distinct tracks played per user (`count`) and grouped the resulting data by `systemuserid` to get the total count of unique/distinct tracks played. The final step was to create a new frame with this `frequency`, then group by the `frequency` and `size()` to get the number of users who have played distinct/unique tracks N times. This results in an ordered list like: `[1, 11794]`, `[2, 7912]`, `[3, 7072]`, `[4, 6763]`, `[5, 6612]`. This is interpreted as “11 794 users have played 1 distinct/unique tracks”.

Pseudo code

```
1 df.groupby(['systemuserid', 'trackid']).size().to_frame('count').  
   reset_index().groupby('systemuserid').size().to_frame('frequency')  
   .reset_index().groupby('frequency').size().reset_index()
```

Expected results

We expect to see a lot of system users playing a few tracks a few times. In other words, we expect that this frequency distribution to also follow Benford's law. We consider it suspicious when encountering noticeable deviations from the expected curve.

4.7 System user frequency: Analysis method 7

The results from the previous analysis step (Subsection 4.6), we can see a suspiciously high count of eighteen distinct tracks. It is common knowledge that music albums usually contain approximately thirteen and eighteen tracks. Therefore, it is possible this spike was caused by a new album release. To determine if this was the case, we analysed the users with this abnormal count/frequency found in the previous step. We first had to extract the system users based on the frequency with the following lines of code:

Listing 4: Extracting all relevant systemuserid

```
1 a7_temp = df.groupby(['systemuserid', 'trackid']).size().
   to_frame('count').reset_index().groupby('systemuserid').size
   ().to_frame('frequency').reset_index()
2 list_systemuserid = a7_temp[a7_temp['frequency'] == 18]['
   systemuserid'].values
3 df = df[df['systemuserid'].isin(list_systemuserid)]
```

The variable `a7_final` will now contain a subset of the original data. A subset which corresponds to all `systemuserid` with the abnormal frequency of playing exactly eighteen distinct/unique tracks.

Purpose, objective or hypothesis

This analysis focuses on a subset of the records/rows for date 2016-01-28, where the abnormal count in played distinct tracks occurred. We focused our attention on the tracks, system users (including their country) and offline or online plays. The goal is to determine if any tracks have been significantly boosted by these system users, whether offline plays could have played a role, and determine if there was a common origin country for the users.

Verbatim description of the analysis

1. Group by the `trackid` and do `size()` to get the count for how many times that track ID occurs in the dataset. Create a new frame and sort those values, having the most played track first.
2. Extract the songs with the significant higher count of plays, and group the result by `offlineplay` to compare the online plays vs the offline plays.
3. Group by `systemuserid` and `countrycode`, then `size()` and finally group by `countrycode` and `size()` to find the number of unique/distinct `systemuserid` from which country.

Pseudo code

1. `top_songs = df.groupby('trackid').size().to_frame('count').reset_index().sort_values(by='count', ascending=False)[:18]['trackid'].values`
2. `df = df[df['trackid'].isin(top_songs)]; df.groupby('offlineplay').size().to_frame('count').reset_index()`
3. `df.groupby(['systemuserid', 'countrycode']).size().to_frame('count').reset_index().groupby('countrycode').size().to_frame('count').reset_index()`

Expected results

1. A list with how many times track t_i have been played by those system users. Any abnormally high count could be caused by a release by a new album. Then we can analyse the timestamps to confirm it was caused by the release of a popular new album.
2. Two numbers that counts the number of online and offline plays. We would expect to see more online plays from a streaming service, however, previous results have shown an almost even (50/50) split between offline and online plays. Therefore, we expect to find this even split also in this results.
3. Numbers for how many distinct system users are from which country. These country counts may be affected by geolocation obfuscation (through proxies or VPNs) depending on how they determine and store country codes for profiles.

4.8 Binning: Analysis method 8

Purpose, objective or hypothesis

Having identified a significant number of timestamps that are not for that specific day in each of the different log files. We investigated the extent these playbacks affected the results, by determining how many they are and whether they show the similar anomalies.

Verbatim description of the analysis

To check this we first split the data into bins based on the year in the timestamp. We created four bins: one for the exact date, one for +/- 2 years from 2016 (i.e. between 2014 and 2018), one for everything prior to 2014 and a last bin for everything post 2018. After sorting the data into four bins, we ran analysis methods 3, 4, 5 and 6 on each separate bin. We also normalised the result values, however, this did not provide any further information. Therefore, we chose not to normalise the results.

Pseudo code

This is a short snippet for how the dataset was split into separate bins. All rows with the exact date was first put into their own bin, before these rows was removed from the data.

Then we identified rows within two years of 2016 and put them into another bin, and removed them from the data. This was then repeated for the two final bins, until all rows was in their corresponding bin. Finally, we could run our previous analysis methods on each bin.

Listing 5: Splitting the dataset into four bins

```

1 bins_split = {'min': '2014', 'exact': argv[0][11:].replace('_', '-'),
2             , 'max': '2018'}
3 bins = {'below': None, 'around': None, 'exact': None, 'above': None}
4 bins['exact'] = df.loc[df['playdatetime'].str.startswith(bins_split[
5     'exact'])].copy().reset_index(drop=True)
6 df = df.drop(bins['exact'].index.values)
7 bins['around'] = df.loc[(df['playdatetime'].str[:4] >= bins_split['
8     min']) & (df['playdatetime'].str[:4] <= bins_split['max'])].copy
9     ().reset_index(drop=True)
10 df = df.drop(bins['around'].index.values)
11 bins['below'] = df.loc[(df['playdatetime'].str[:4] < bins_split['min
12     '])].copy().reset_index(drop=True)
13 df = df.drop(bins['below'].index.values)
14 bins['above'] = df.copy().reset_index(drop=True)
15 df.drop(bins['above'].index.values)

```

Expected results

We expect to find that most of the rows is contained in the bin for exact date. The **around**-bin (with timestamp +/- 2 years around 2016) should have the second highest count of rows, as this should incorporate systems without rigorous time synchronisation scheme and smaller devices lacking synchronisation capabilities. A minimum of rows should be contained in the two final bins. However, rows found in those bins cannot be automatically called suspicious, as there could be a number of explanations for their timestamp. Running the previous analysis steps again, particularly for date 2016-02-14 and analysis method 6 (Subsection 4.6, should reveal in which bin the anomalies are found.

4.9 Modulo six: Analysis method 9

Purpose, objective or hypothesis

The client noticed that multiple playbacks (with the same track ID) ended on identical seconds and milliseconds, while the hour and minutes differed. From a small subset of system users, they had identified that two timestamps with this characteristic could be divided by six minutes. That is, the time difference between $t_1 = 2016-04-28\ 05:54:26.156$ and $t_2 = 2016-04-28\ 07:12:26.156$ is 1 hour and 18 minutes, which is evenly divisible by six minutes. Another way to illustrate this is to convert the difference into seconds, *1 hour and 18 minutes = 4680 seconds* and *six minutes = 360 seconds*. Taking $4680 \bmod 360 = 0$ show that the time difference between those two playbacks is evenly dividable by six minutes. The modulo operation finds the remainder after division of one number by another. Modulo show no remainder after dividing $(t_1 - t_2)$ with six minutes.

Verbatim description of the analysis

Assuming two playbacks have the same system user ID and track ID:

1. Find occurrences of two playbacks which varies by minutes dividable by six minutes (e.g. 6 min, 12 min, 18, min, 24 min, 30 min, etc).

Pseudo code

1. See Appendix F

Expected results

There is a very low probability that any user would seemingly randomly play the same track on two different times; with a time ending on the same second and milliseconds. Therefore, we do not expect to find a high number of these occurrences, although it would still be statistically possible for this happening for a few users.

5 Findings

This chapter summarises the findings for each of the analysis methods, in the same order the analysis methods were executed. Analysis method 2 is discussed toward the end of this section as while it was a task planned for earlier in the analysis of the data, requests from the client meant that the analysis was carried out at a later stage. This did not cause any issue or difference in the analysis of the data.

5.1 Descriptive statistical analysis findings

The findings from analysis method 1 are described in Section 3, including figures found therein. Instead of repeating the findings here, we only describe some interesting observations of the data.

Figure 2 shows a steady number of log entries in the first period, until a significant spike on 2016-02-14 until 2016-02-23. The steady number was between 9-10 million, while the spike is as much as 52 million log entries on 2016-02-14. This results in a 477.78% increase of log entries in just one day. This is almost inconceivable and as such is suspicious. The increase in log entries continued for a total of nine days before dropping down to a little under 20 million per day for the rest of the period. A similar spike in log entries occurs in the second period; however, in that case the number of log entries steadily decline after the initial spike on 2016-04-24/25.

Although the numbers of log entries increase at a large rate, these numbers could be explained by the increase of system users shown in Figure 5. The number of unique users went from 358 217 on 2016-02-13, to 691 041 on the day after. Nearly a doubling (92.91% increase) in the number of unique users playing songs per day. However, the next analysis steps will demonstrate that these increases in playbacks are not caused by system users. A doubling in the number of playbacks are a logical conclusion when the amount of system users also doubles. This is consistent with what we see in the dates which are not affected by the sudden spikes in playbacks. For example, 2016-02-13 had about 10 million playbacks, while 2016-02-24 had about 20 million playbacks. Thus, 60 million playbacks for the two suspicious spikes cannot be caused by the system users alone.

We associate music streaming to be on-demand and online, so we would expect to find a lot more online log entries. It is, therefore, an interesting observation that the percentage between online and offline log entries are almost evenly split. We suspect that this is a normal user behaviour since this split remains steady during the entire period. Independently of the large spikes we see in both periods.

5.2 Unique tracks per user findings

Analysis method 3 counts how many times unique/distinct tracks has been played per user. For example, “436249 tracks have been played 2 times” for a particular day. The curves for the normal days in the first period (except dates between 2016-02-14 and 2016-02-23) followed our expectations. I.e. users play unique tracks just a few times, and follow the Benford’s law. It is noteworthy that the curve also followed our expectation on 2016-01-28. We will come back to the significance of this date in Subsection 5.4 and 5.5.

Figure 7 shows the curves for all days in the first period. In the suspicious days, there are distinct frequencies for how many unique tracks are being played per user. This appears to follow some multiplicity of three, with spikes appearing on three, six, nine and twelve. This result show that system users are recorded to play unique tracks exactly three times, than playing unique tracks two or four times. Table 1 demonstrates how many times (count) which unique tracks has been played exactly three times.

trackid	numuplays	count
57273409	3	117533
57273414	3	115518
57273416	3	108465
57273413	3	107218
57273410	3	107195
57273417	3	106766
57273412	3	106219
57273411	3	106055
57273415	3	105983
57317919	3	101238
57273419	3	95899

Table 1: Example count for date 2016-02-14

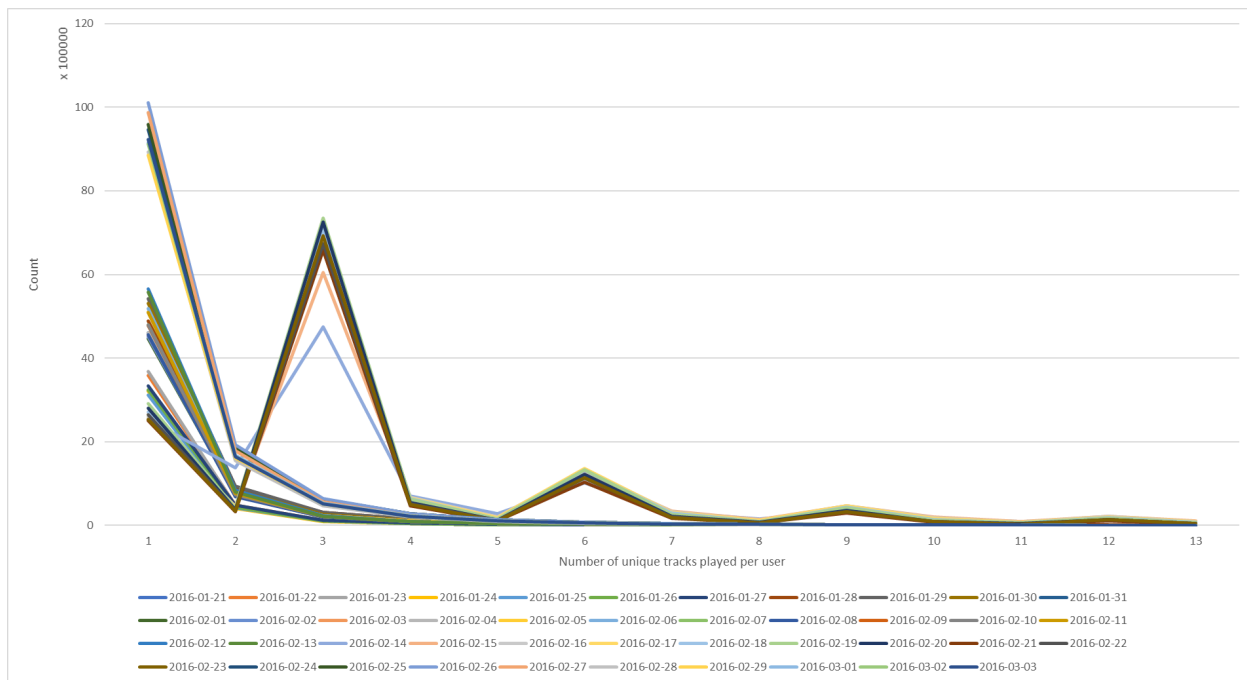


Figure 7: Analysis method 3 results period 1

The curves for the second period, as show in Figure 8, generally follow our expectation. A little surprising was occurrences of one individuals with really high number of times playing unique tracks, for example, user with ID X played track Y a total of 346 times on 2016-05-01. All days had a few users with this high amount of plays for unique tracks, however, we could not find anything suspicious about them.

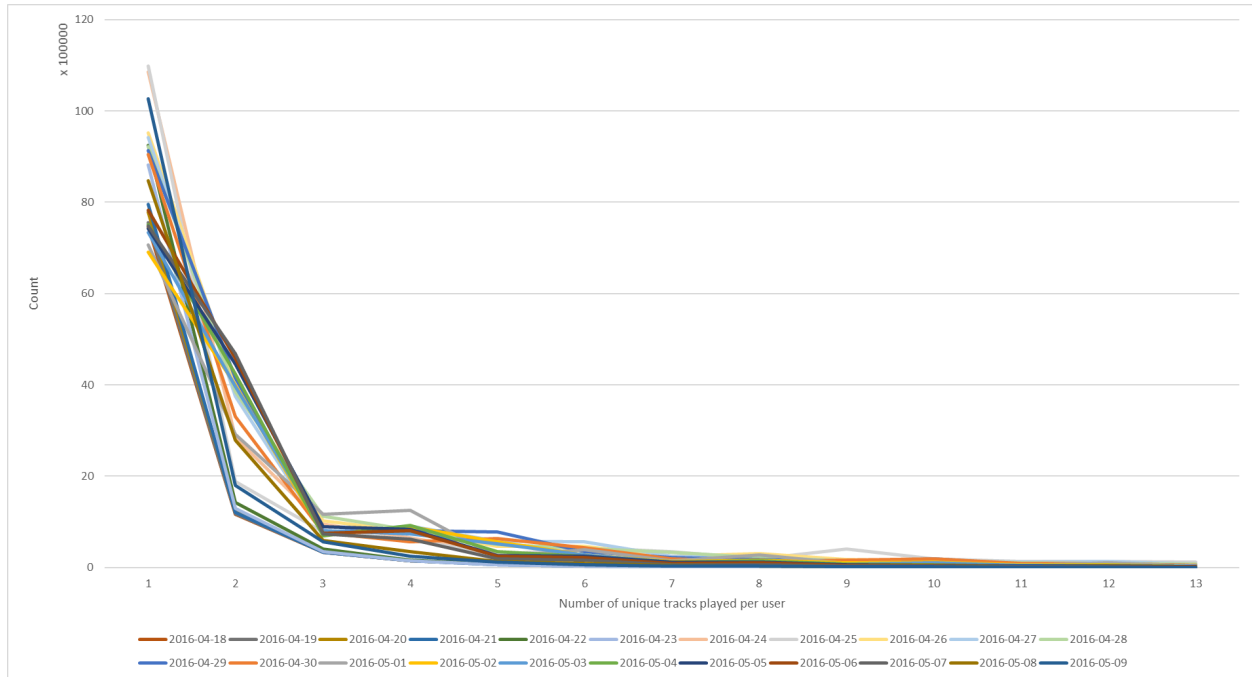


Figure 8: Analysis method 3 results period 2

5.3 Tracks per user findings

Analysis method 4 counts the number of tracks played per user. For example, “9778 users have played 1 tracks” for a particular day. We again see that the curves for normal days generally follow our expectations. Users normally play a lower number of tracks each day, with a few exceptions by users with up to three thousands plays for a day.

Figure 9 show a small bump for date 2016-01-28 (a red curve) at 13, which we will come back to in Subsection 5.4 and 5.5. This figure demonstrates that a lot of users had listened to tracks with a multiplicity of three. The sawtooth-shaped curves are only found during the suspicious ten days in the first period. Table 2 demonstrates how many users had played exactly count tracks for a particular day.

count	users
3	25012
6	18545
9	13962
12	13760
18	13605
15	12329
21	10703
1	10168
2	10141
24	9994
54	9400

Table 2: Example count for date 2016-02-14

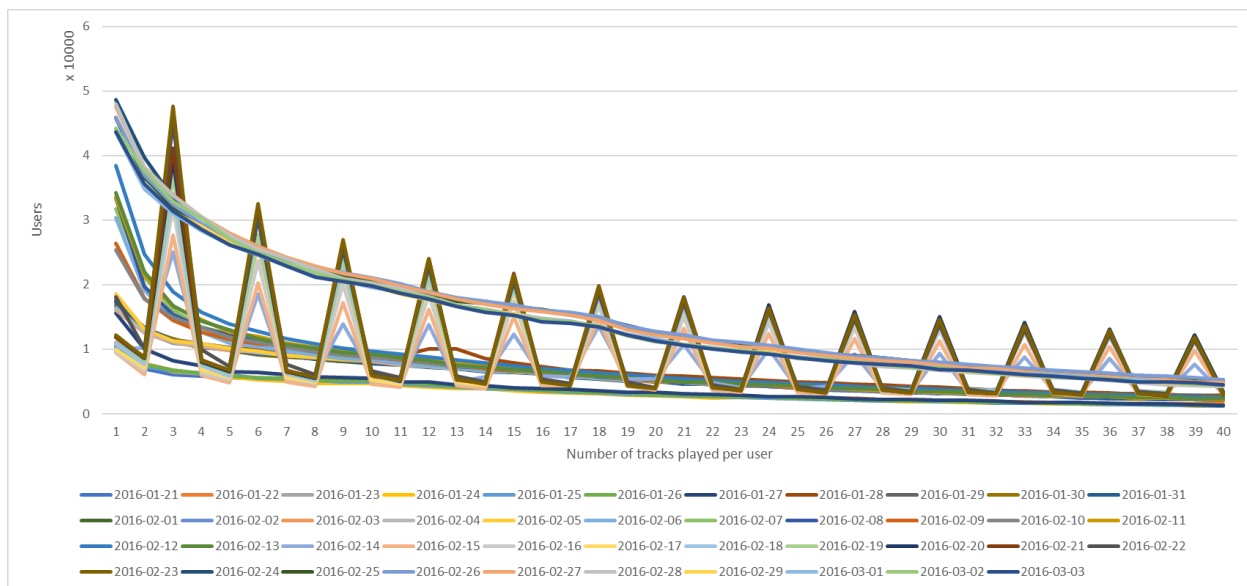


Figure 9: Analysis method 4 results period 1

While we did not see anything suspicious abnormalities for the second period in the previous analysis step, this step clearly demonstrates that something is happening on some of these dates. However, this time it appears to be a multiplicable of two. The general curve also appears to have been smoothed, so it does not have the same high spikes as in the first period.

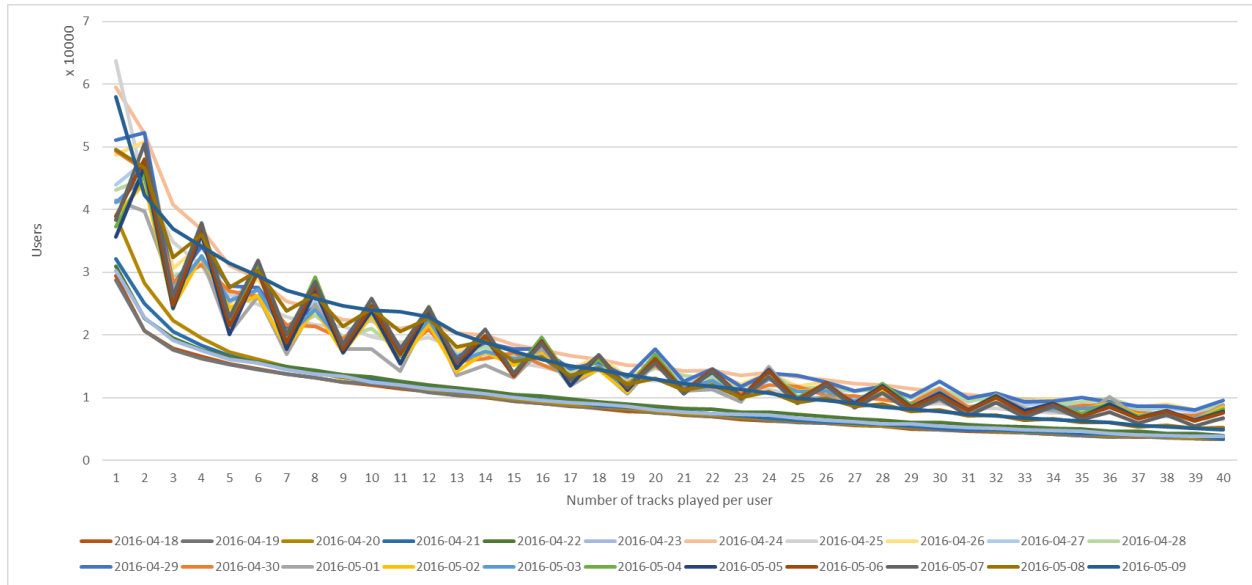


Figure 10: Analysis method 4 results period 2

5.4 Popular track findings

Figure 9 show two album releases during the same period. The first album was ‘Anti’ by Rihanna on 2016-01-28, which was made available for free digital download on 2016-01-27¹. The difference between these two dates should come from the timezone of the log server and what is reported on Wikipedia. The second album was ‘Life of Pablo’ by Kanye West on 2016-02-14². Subsection 5.5 also suggests that there was two large albums released in the first period. We have extracted the top played tracks on these two dates using analysis method 5. The results is found in Table 3.

The top thirteen tracks played on 2016-01-28 was all from Rihanna’s album, with a total of 4 413 802 playbacks on this day alone. The highest track – not related to this album – was Formation (trackid: 57034935) by Beyoncé. The top eighteen tracks played on 2016-02-14 was all from Kanye’s album, with a total of 33 331 035. Kanye’s album had 655.15% more playbacks than Rihanna’s album on their release dates. Table 4 gives an overview over which track IDs belongs to which album. The track IDs in parentheses are tracks which was added to Kanye’s album at later dates. Finally, we also identified the album ‘Lemonade’ by Beyoncé Knowles from the suspicious days in the second period.

2016-01-28		2016-02-14	
trackid	frequency	trackid	frequency
56677093	475172	57273410	2629970
56677094	404041	57273409	2517090
56677092	401949	57273412	2467229
56677090	383417	57273411	2414477
56677096	378201	57317924	2279144
56677095	353840	57273413	2154190
56677097	335576	57273418	2128204
56677091	313186	57273415	1890142
56677098	310798	57273414	1811385
56677101	295793	57273420	1773354
56677100	277148	57273416	1770112
56677102	242758	57273419	1644453
56677099	241923	57273417	1503686
56638583	67930	57317920	1387581
53960289	14580	57317923	1379380
51004025	14498	57317922	1235945
52901260	14390	57317919	1219114
53893678	14272	57317921	1125579
56290510	13691	57034935	288953
54511031	11280	56681096	155993
56677107	11242	57040670	139501
44094250	10059	57261945	123683
47497148	10028	56681099	114072
48351965	9682	56681097	108889
49671724	8987	56681095	92878
56677108	8925	56681093	87684
56372041	8783	56681100	87681
45323542	8688	56638583	83157
56677106	8401	56681098	80910
51579781	8166	56681101	74448

Table 3: Top 30 played tracks

¹[https://en.wikipedia.org/wiki/Anti_\(album\)](https://en.wikipedia.org/wiki/Anti_(album))

²https://en.wikipedia.org/wiki/The_Life_of_Pablo

‘Anti’ by Rihanna		‘Life of Pablo’ by Kanye West	
trackid	Title	trackid	Title
56677090	Consideration (feat. SZA)	57273409	Ultralight Beam
56677091	James Joint	57273410	Father Stretch My Hands Pt. 1
56677092	Kiss It Better	57273411	Pt. 2
56677093	Work	57273412	Famous
56677094	Desperado	57273413	Feedback
56677095	Woo	57273414	Low Lights
56677096	Needed Me	57273415	Highlights
56677097	Yeah, I Said It	57273416	Freestyle 4
56677098	Same Ol’ Mistakes	57273417	I Love Kanye
56677099	Never Ending	57273418	FML
56677100	Love On The Brain	57273419	Real Friends
56677101	Higher	57273420	Wolves
56677102	Close To You	57317919	Siiiiiiiilver Surffffeeeeeer Intermission
		57317920	30 Hours
		57317921	No More Parties in LA
		57317922	Facts (Charlie Heat Version)
		57317923	Fade
		57317924	Waves
		(58373775)	Frank’s Track
		(61872799)	Saint Pablo

‘Lemonade’ by Beyoncé Knowles	
trackid	Title
59727857	Pray you catch me
59727858	Hold up
59727859	Don’t hurt yourself
59727860	Sorry
59727861	6 inch
59727862	Daddy lessons
59727863	Love drought
59727864	Sandcastles
59727865	Forward
59727866	Freedom
59727867	All night
59727868	Formation
59727870	Pray you catch me
59727871	Hold up
59727872	Don’t hurt yourself
59727873	Sorry
59727874	6 inch
59727875	Daddy lessons
59727876	Love drought
59727877	Sandcastles
59727878	Forward
59727879	Freedom
59727880	All night
59727881	Formation

Table 4: Track IDs overview

5.5 Number of unique tracks findings

After the results from analysis method 4, in Subsection 5.3, we wanted to look closer at the number of unique/distinct tracks played per system user. Figure 11 show a small spike when Rihanna’s album was released, when she was fully signed with her manager Jay Z’s company *Roc Nation*. The next smaller bump at 16 is track IDs from the same Rihanna album but with different track IDs. The largest spike in the first period is exclusively caused by users listening to Kanye’s album.

A notable distinction between these albums is that Kanye’s ‘Life of Pablo’ continued to have unnatural high number of playbacks over several days. Although both Kanye and Rihanna have somewhat similar popularity, Rihanna’s album flattened out much quicker. Even if this particular music streaming platform could have a certain userbase, we would expect Kanye’s spike to react in a similar fashion as Rihanna’s spike. That is, a small spike (not quite as high as indicated by the figure) and then a fast decline and normalisation of the numbers.

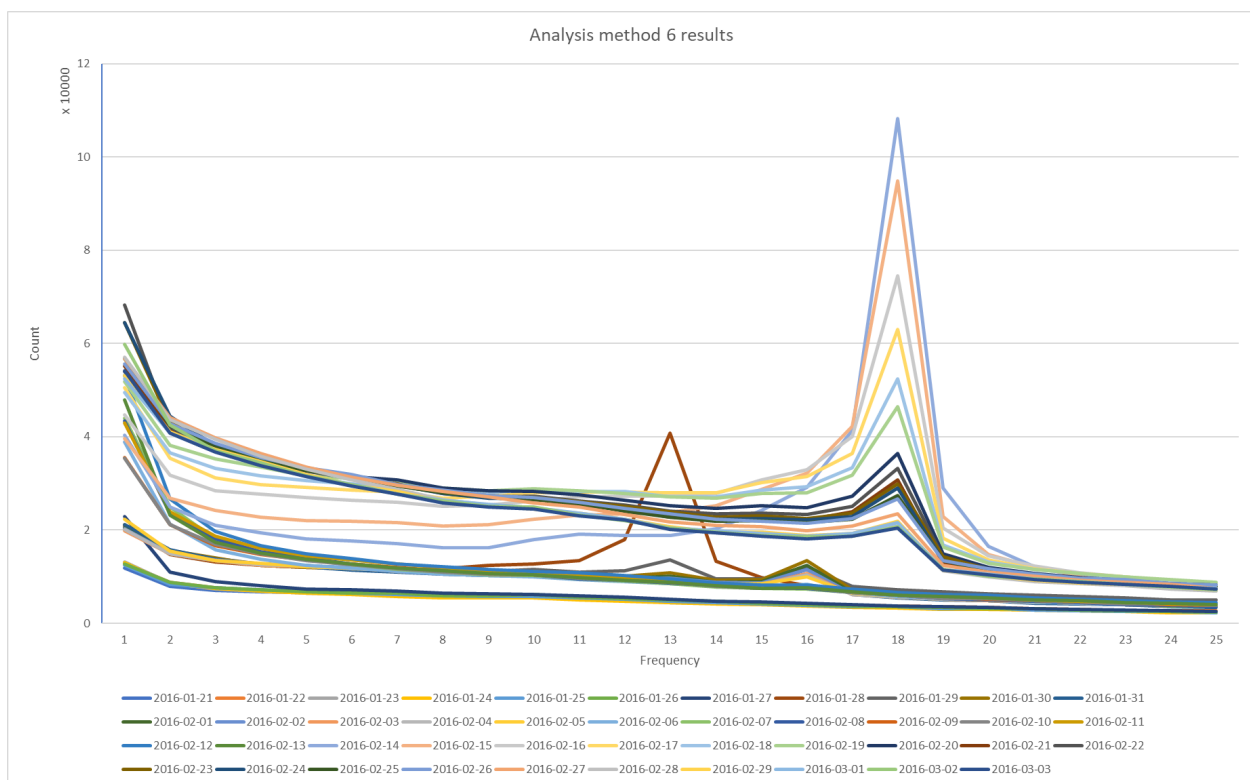


Figure 11: Analysis method 6 results

Figure 12 show that Beyoncé’s album have a similar behaviour as we found for Kanye’s album. Beyoncé is married to Jay Z (Shawn Corey Carter). Her album was released on 2016-04-23, however, the time when this occurs in the logs is on 2016-04-24. A difference that can be explained by the different timezones for the log server and the release information found online.

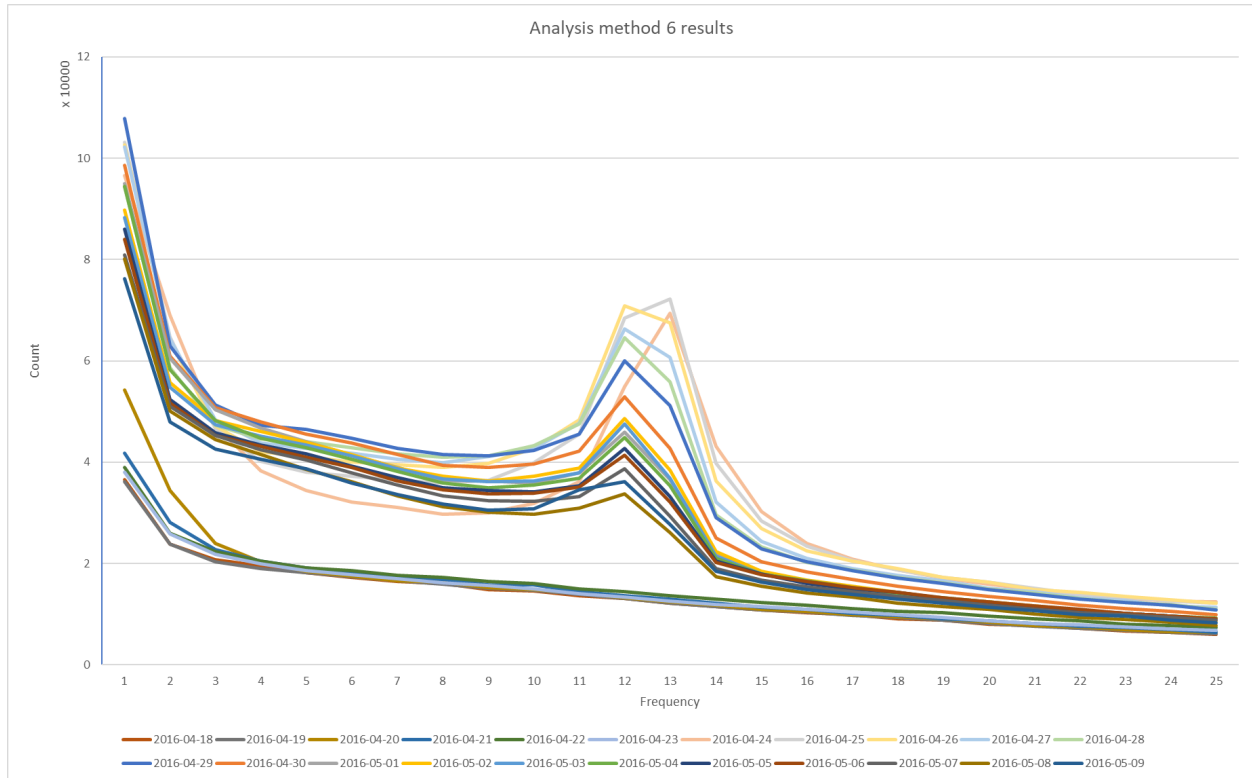


Figure 12: Analysis method 6 results

5.6 System user frequency findings

It is suspicious the extent to which users would choose to selectively listen to eighteen particular tracks in the first period, and twelve to thirteen tracks in the second period. We would expect them to be more similar behaviour as Rihanna's album: a small spike in interest for the album on release day, and then quickly subside. However, previous analysis steps show that this was not the case for 'Life of Pablo' and 'Lemonade'. The next natural step is to find out more about the system users who listened to these tracks. Figure 13 show that tracks from 'Life of Pablo' was played a lot more than any other track ID on 2016-02-14. However, when looking at the offline playback for these top 18 played tracks, we see they are played a lot more offline than online (Figure 14). Finally, finding the countries, Figure 15, where the users are from gave nothing interesting.

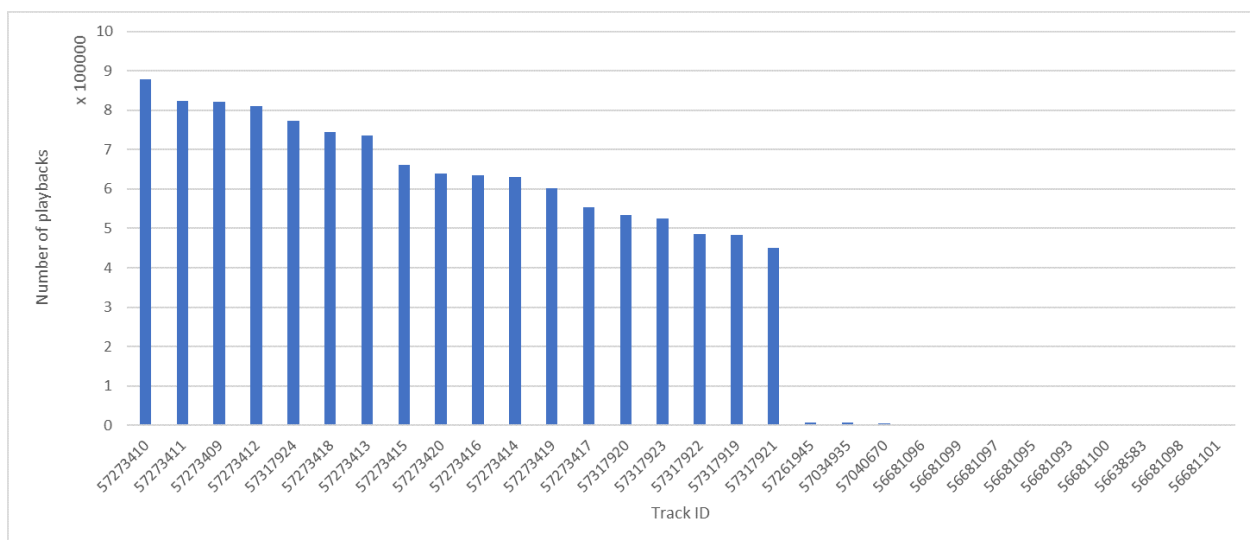


Figure 13: Top 30 played tracks on 2016-02-14

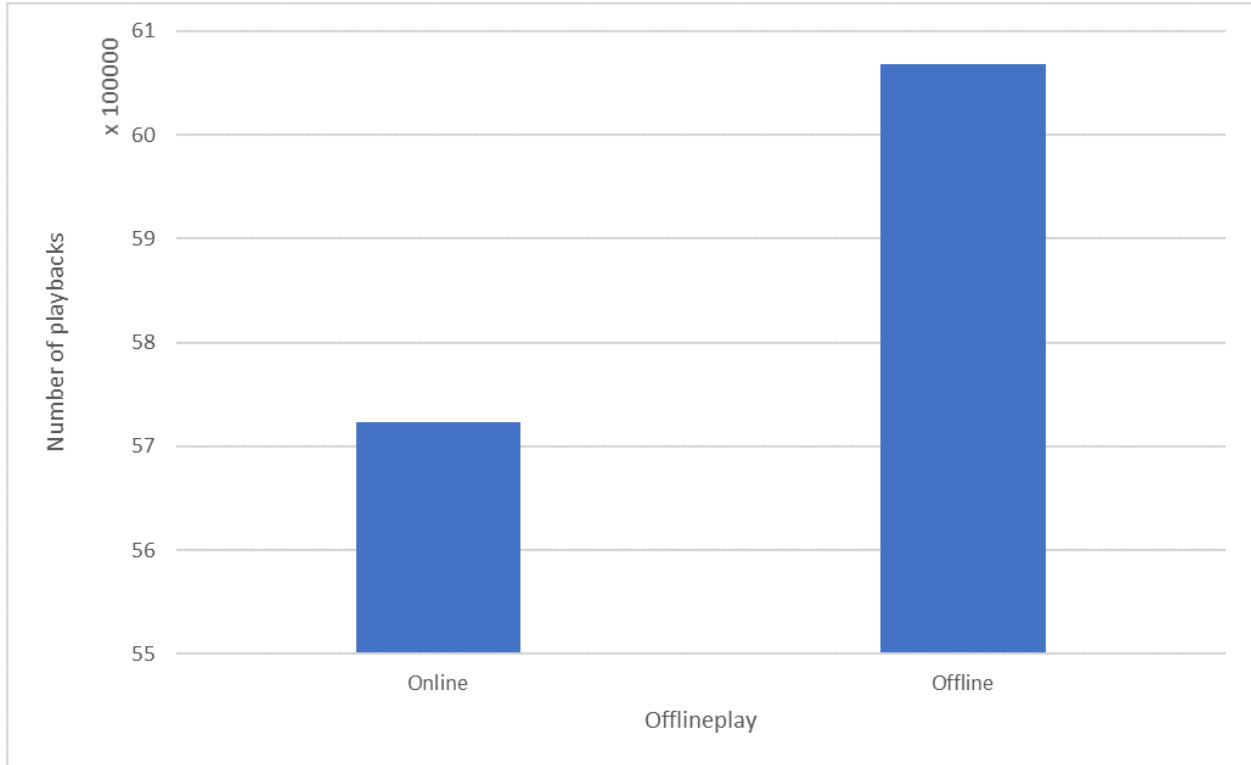


Figure 14: Top 18 tracks offline play on 2016-02-14

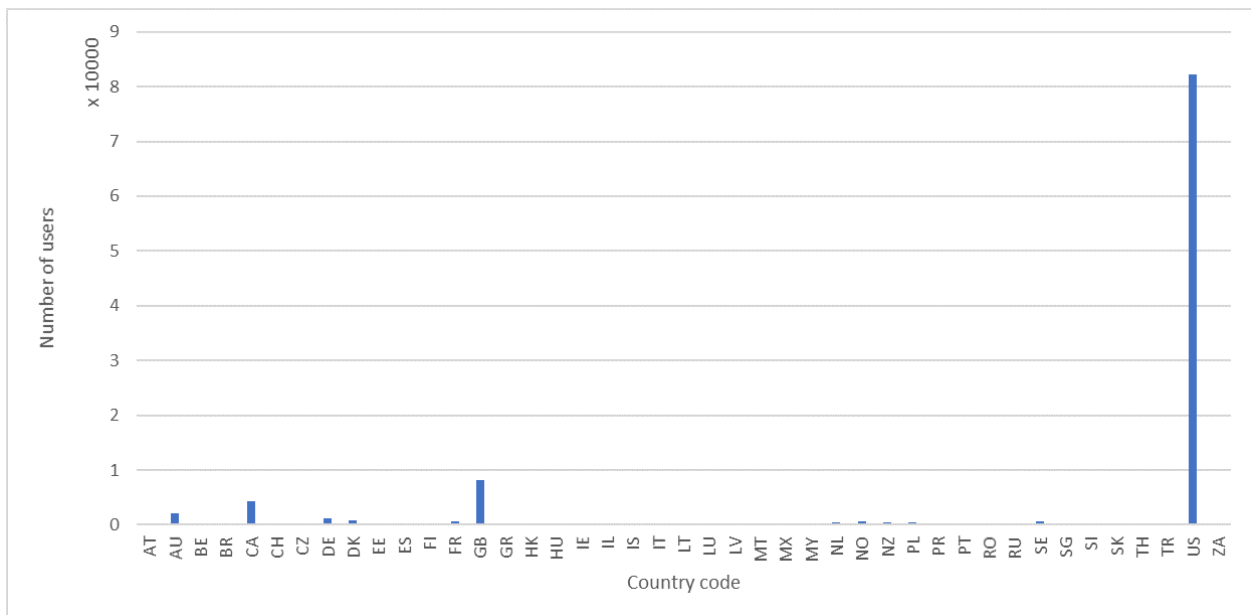


Figure 15: Countries playing the top 18 tracks on 2016-02-14

5.7 Binning findings

We identified some anomalies in the data, specifically the large amount of users listening to the , so it was necessary to understand the system users they affect. For this we divided the log entries into four distinctive bins based on the year in their timestamp. A short reminder for these bins: *exact* contains log entries for that exact date (respectively for the log file currently under investigation), while *around* contains any rows found +/- 2 years from 2016 (i.e. between 2014 and 2018). The two remaining bins *below* and *above* captures any remaining log entries with years prior to 2014 and post 2018 respectively.

Figure 16 show the analysis method 6 for each bin. The bins *below* and *above* is barely visible, while *around* follows our expectations. Note that when looking at the actual number, these three bins does not have the elevated spike on eighteen in frequency. This result suggests that log entries found with weird timestamps have a very low to no effect on the overall results found in previous analysis steps. Furthermore, this show that those users have not been tampered with. Finally, the figure show that most of the log entries can be found around or on the exact date. Which means that log entries from the two smallest bins (i.e. below and above) can be removed when necessary.

Figure 16 show that the characteristics found in analysis method 6 only affects log entries in the *exact*-bin. Which means that they where the only ones who showed this abnormal behaviour.

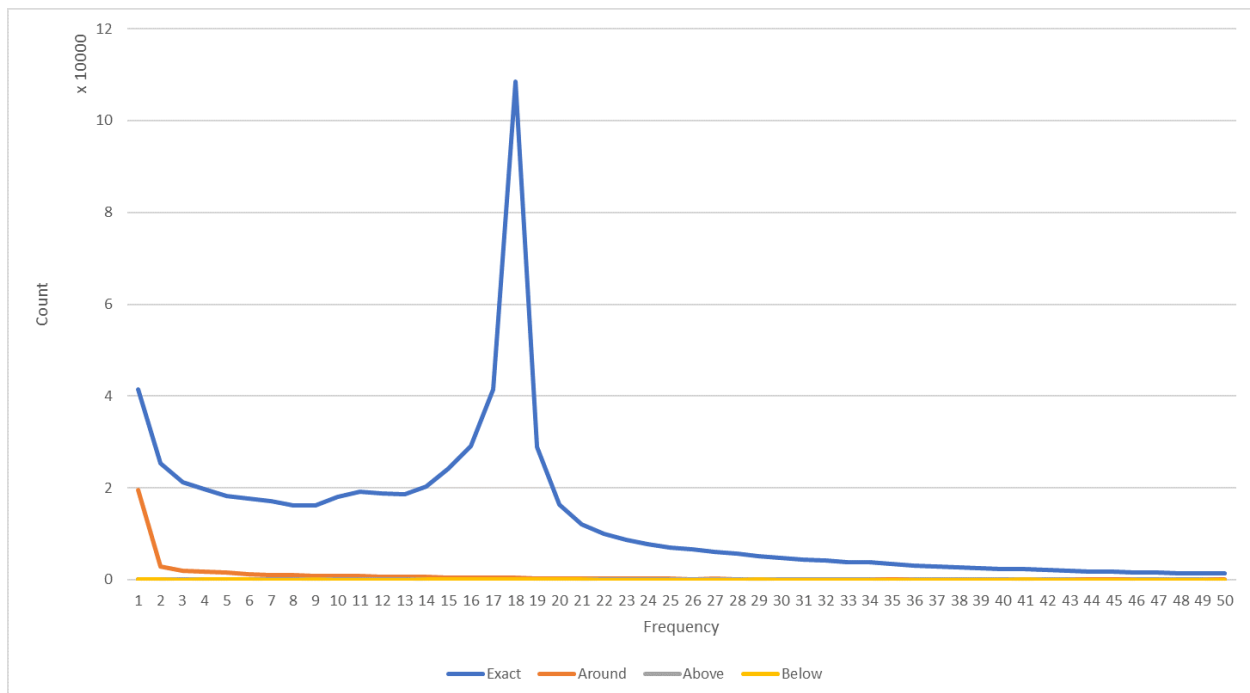


Figure 16: Analysis method 8 findings for 2016-02-14

5.8 Impossible scenario findings

As previously explained at the beginning of 5 Analysis Method 2 was conducted later in the investigation. As such, Analysis Method 2 is presented here, between the findings that preceded and followed Analysis Method 2. This analysis method was conducted later due to specific requests of DN. As each form of statistical analysis is independent of the other, it is of no consequence the order in which the analysis was carried out. For this analysis we set out to identify occurrences of “impossible” scenarios. This includes four scenarios where the time and system user ID is identical: 1) with two identical tracks; 2) with three or more identical tracks; 3) with two unequal tracks; and 4) with three or more unequal tracks. We refer the reader back to Subsection 4.2 for an explanations about the difference between the terms ‘identical’ and ‘unequal’.

The results from this analysis are in three different tables for each impossible scenario. The first table describes the *unique* system users found for each day (i.e. each user is only counted once), and how many of those was affected by the impossibility. An ‘online’ system user is anyone with at least one online playback for that day, while ‘offline’ users exclusively have offline playbacks. However, online system users can also have offline playbacks.

The second table focuses on the *unique* playbacks (log entries) found for each day. It will describe how many playbacks was affected by the impossible scenario. In addition, it describes whether the affected playbacks was online or offline. ‘Online’ playbacks in this table are any log entry marked as being played online, while ‘offline’ playbacks are marked as offline, ‘N’ or ‘Y’ respectively.

The third table enriches information found in the two previous tables. This table shows online users’ online and offline playbacks. Thus, we can identify which of their playbacks was affected by these impossible scenarios. It also shows the same information for offline users, however, they do not have any online playbacks because of our definition of offline users.

Finally, the third table also show how many of those affected playbacks (found in the second table) are from the two albums we previously identified in other analysis steps. More specifically: ‘Life of Pablo’ by Kanye West and ‘Lemonade’ by Beyoncé Knowles. A list with the track’s IDs are found in Table 4. Note that each album is only counted in their respective periods, to understand how many of the affected playbacks are from each individual album.

Table 5 contains the results for system users which had exactly two identical duplicates for each day. Users affected with this characteristic occurred about five percent per each day in both periods. Although we had expected a lower percentage, we have an understanding that the logging system could sometimes incorrectly log one playback twice. We are unaware of how frequent this system error occurred. However, the next tables can help give an understanding for when it occurred.

While Table 5 only looks at the affected users with exactly two identical duplicates, Table 6 looks at the affected log entries themselves. Here, we can see that they normally affect about one percent of the total playbacks per day. It is also noteworthy that they only affected offline playbacks, which is most likely caused by those devices who produce very strange timestamps. However, the exception to our observation is in the suspicious days in the first period, between 2016-02-14 and 2016-02-23. Online playbacks was also affected in this short period of ten days.

Table 5 show that online users (i.e. who have at least one online playback) are affected by

having two identical duplicates. However, Table 7 contains playbacks for affected users only. This clearly show that this only happened to offline playbacks. Again, with the exception of those ten days.

Date	Total users	Affected users	Affected users %	Total online users	Affected online users	Affected online users %	Total offline users	Affected offline users	Affected offline users %
2016-01-21	174620	7704	4.412	135221	5109	3.778	39399	2595	6.586
2016-01-22	188796	8592	4.551	149491	5841	3.907	39305	2751	6.999
2016-01-23	183237	7460	4.071	148330	5176	3.49	34907	2284	6.543
2016-01-24	171511	6958	4.057	137257	4812	3.506	34254	2146	6.265
2016-01-25	174896	7850	4.488	135543	5127	3.783	39353	2723	6.919
2016-01-26	180917	8020	4.433	140482	5412	3.852	40435	2608	6.45
2016-01-27	202757	28771	14.19	165342	20699	12.519	37415	8072	21.574
2016-01-28	356158	15844	4.449	307284	12788	4.162	48874	3056	6.253
2016-01-29	344910	16998	4.928	277724	12813	4.614	67186	4185	6.229
2016-01-30	324098	14662	4.524	254269	10593	4.166	69829	4069	5.827
2016-01-31	296886	12705	4.279	225798	8696	3.851	71088	4009	5.639
2016-02-01	300715	14548	4.838	222513	9575	4.303	78202	4973	6.359
2016-02-02	300530	14615	4.863	221130	9697	4.385	79400	4918	6.194
2016-02-03	296753	14221	4.792	216748	9409	4.341	80005	4812	6.015
2016-02-04	298583	14647	4.906	217279	9674	4.452	81304	4973	6.117
2016-02-05	312045	15187	4.867	234200	10397	4.439	77845	4790	6.153
2016-02-06	330846	13920	4.207	270729	10284	3.799	60117	3636	6.048
2016-02-07	337341	12624	3.742	287555	9781	3.401	49786	2843	5.71
2016-02-08	334768	14672	4.383	278546	11214	4.026	56222	3458	6.151
2016-02-09	328425	14635	4.456	260760	10516	4.033	67665	4119	6.087
2016-02-10	328089	14660	4.468	257006	10420	4.054	71083	4240	5.965
2016-02-11	355004	14795	4.168	281945	10488	3.72	73059	4307	5.895
2016-02-12	386880	15941	4.12	316405	11733	3.708	70475	4208	5.971
2016-02-13	358217	14293	3.99	291055	10548	3.624	67162	3745	5.576
2016-02-14	691041	363757	52.639	609112	331135	54.364	81929	32622	39.817
2016-02-15	747981	429170	57.377	574979	338434	58.86	173002	90736	52.448
2016-02-16	800171	455094	56.875	585803	343981	58.72	214368	111113	51.833
2016-02-17	815881	458633	56.213	574861	334762	58.234	241020	123871	51.394
2016-02-18	806257	440539	54.64	551943	315342	57.133	254314	125197	49.229
2016-02-19	817275	436639	53.426	556034	311420	56.007	261241	125219	47.932
2016-02-20	787117	399162	50.712	532886	286690	53.799	254231	112472	44.24
2016-02-21	732423	345356	47.153	486737	246436	50.63	245686	98920	40.263
2016-02-22	770746	370496	48.07	533728	271442	50.858	237018	99054	41.792
2016-02-23	764584	373093	48.797	529906	275788	52.045	234678	97305	41.463
2016-02-24	760152	36184	4.76	514411	23142	4.499	245741	13042	5.307
2016-02-25	747083	36595	4.898	496204	23373	4.71	250879	13222	5.27
2016-02-26	764275	37034	4.846	512378	24222	4.727	251897	12812	5.086
2016-02-27	741229	31397	4.236	494773	20657	4.175	246456	10740	4.358
2016-02-28	696194	27857	4.001	459151	17970	3.914	237043	9887	4.171
2016-02-29	691263	33240	4.809	449202	20931	4.66	242061	12309	5.085
2016-03-01	696388	33094	4.752	454878	21059	4.63	241510	12035	4.983
2016-03-02	700917	32573	4.647	461109	20799	4.511	239808	11774	4.91
2016-03-03	691915	32836	4.746	451042	21013	4.659	240873	11823	4.908
2016-04-18	461253	25089	5.439	340662	18112	5.317	120591	6977	5.786
2016-04-19	463153	25454	5.496	343033	18529	5.402	120120	6925	5.765
2016-04-20	504825	27172	5.382	402684	21197	5.264	102141	5975	5.85
2016-04-21	494942	25544	5.161	392501	19465	4.959	102441	6079	5.934
2016-04-22	530312	28734	5.418	429837	22468	5.227	100475	6266	6.236
2016-04-23	500494	24205	4.836	398927	18658	4.677	101567	5547	5.461
2016-04-24	1017351	41223	4.052	937338	36983	3.946	80013	4240	5.299
2016-04-25	1084330	52209	4.815	936931	43237	4.615	147399	8972	6.087
2016-04-26	1106615	83979	7.589	921532	66381	7.203	185083	17598	9.508
2016-04-27	1086552	52833	4.862	878715	40944	4.66	207837	11889	5.72
2016-04-28	1066626	52393	4.912	841933	40006	4.752	224693	12387	5.513
2016-04-29	1079856	51129	4.735	854740	39335	4.602	225116	11794	5.239
2016-04-30	1005141	173312	17.243	778704	132664	17.037	226437	40648	17.951
2016-05-01	922822	36300	3.934	703029	26947	3.833	219793	9353	4.255
2016-05-02	923637	60944	6.598	690843	44603	6.456	232794	16341	7.02
2016-05-03	912692	41667	4.565	668396	29758	4.452	244296	11909	4.875
2016-05-04	919118	41653	4.532	683132	29859	4.371	235986	11794	4.998
2016-05-05	889725	40945	4.602	659028	29640	4.498	230697	11305	4.9
2016-05-06	887489	41820	4.712	658611	30740	4.667	228878	11080	4.841
2016-05-07	851475	37153	4.363	628638	27294	4.342	222837	9859	4.424
2016-05-08	790803	32826	4.151	581512	23845	4.101	209291	8981	4.291
2016-05-09	807714	37653	4.662	590649	26945	4.562	217065	10708	4.933

Table 5: Two duplicates system users

Date	Total play-backs	Affected play-backs	Affected play-backs %	Total online play-backs	Affected online play-backs	Affected online play-backs %	Total offline play-backs	Affected offline play-backs	Affected offline play-backs %
2016-01-21	5183365	58848	1.135	2887796	0	0.0	2295569	58848	2.564
2016-01-22	5699857	63454	1.113	3197499	0	0.0	2502358	63454	2.536
2016-01-23	5706073	56224	0.985	3320763	0	0.0	2385310	56224	2.357
2016-01-24	4990937	55104	1.104	2877218	0	0.0	2113719	55104	2.607
2016-01-25	5034490	58916	1.17	2775176	0	0.0	2259314	58916	2.608
2016-01-26	5211451	57856	1.11	2861114	0	0.0	2350337	57856	2.462
2016-01-27	5699874	175810	3.084	3115105	0	0.0	2584769	175810	6.802
2016-01-28	10716712	94554	0.882	5406227	0	0.0	5310485	94554	1.781
2016-01-29	10860619	102304	0.942	5522217	0	0.0	5338402	102304	1.916
2016-01-30	10008250	89884	0.898	5200705	0	0.0	4807545	89884	1.87
2016-01-31	8445037	78374	0.928	4380686	0	0.0	4064351	78374	1.928
2016-02-01	8595181	91098	1.06	4260810	0	0.0	4334371	91098	2.102
2016-02-02	8469929	91928	1.085	4153867	0	0.0	4316062	91928	2.13
2016-02-03	8386787	90132	1.075	4130617	0	0.0	4256170	90132	2.118
2016-02-04	8410214	96704	1.15	4128894	0	0.0	4281320	96704	2.259
2016-02-05	9001255	102532	1.139	4503223	0	0.0	4498032	102532	2.279
2016-02-06	8841003	106424	1.204	4623472	0	0.0	4217531	106424	2.523
2016-02-07	8375341	89782	1.072	4562874	0	0.0	3812467	89782	2.355
2016-02-08	8145940	89506	1.099	4244968	0	0.0	3900972	89506	2.294
2016-02-09	8439985	94938	1.125	4289622	0	0.0	4150363	94938	2.287
2016-02-10	8437553	94282	1.117	4261212	0	0.0	4176341	94282	2.258
2016-02-11	8748323	102980	1.177	4431643	0	0.0	4316680	102980	2.386
2016-02-12	9591865	103062	1.074	4932532	0	0.0	4659333	103062	2.212
2016-02-13	9207400	99784	1.084	4815322	0	0.0	4392078	99784	2.272
2016-02-14	52264508	6115298	11.701	25683182	2850730	11.1	26581326	3264568	12.281
2016-02-15	62315131	7164866	11.498	28423017	3053831	10.744	33892114	4111035	12.13
2016-02-16	62575347	7341568	11.732	27216556	2938168	10.796	35358791	4403400	12.453
2016-02-17	61635277	7330456	11.893	26096222	2831421	10.85	35539055	4499035	12.659
2016-02-18	58176702	6994444	12.023	24279133	2640953	10.877	33897569	4353491	12.843
2016-02-19	57453384	6920768	12.046	23863079	2570530	10.772	33590305	4350238	12.951
2016-02-20	51238240	6161090	12.024	21695419	2310437	10.649	29542821	3850653	13.034
2016-02-21	44012913	5147548	11.696	19017377	1958538	10.299	24995536	3189010	12.758
2016-02-22	48123726	5730262	11.907	20139829	2136875	10.61	27983897	3593387	12.841
2016-02-23	47818784	5712280	11.946	19908725	2114657	10.622	27910059	3597623	12.89
2016-02-24	19205376	206646	1.076	8020004	0	0.0	11185372	206646	1.847
2016-02-25	19155488	210692	1.1	7933048	0	0.0	11222440	210692	1.877
2016-02-26	19895000	217950	1.096	8316062	0	0.0	11578938	217950	1.882
2016-02-27	18410754	188234	1.022	7817765	0	0.0	10592989	188234	1.777
2016-02-28	16341019	169526	1.037	7006815	0	0.0	9334204	169526	1.816
2016-02-29	17041782	189676	1.113	7049968	0	0.0	9991814	189676	1.898
2016-03-01	17519578	197122	1.125	7264171	0	0.0	10255407	197122	1.922
2016-03-02	17260480	193074	1.119	7182545	0	0.0	10077935	193074	1.916
2016-03-03	17326476	181916	1.05	7175051	0	0.0	10151425	181916	1.792
2016-04-18	13094984	157950	1.206	5480281	0	0.0	7614703	157950	2.074
2016-04-19	13228953	160584	1.214	5561693	0	0.0	7667260	160584	2.094
2016-04-20	13716969	177984	1.298	5943181	0	0.0	7773788	177984	2.29
2016-04-21	13592572	161782	1.19	6080560	6	0.0	7512012	161776	2.154
2016-04-22	15716545	179924	1.145	7204431	0	0.0	8512114	179924	2.114
2016-04-23	14539943	147412	1.014	6686559	0	0.0	7853384	147412	1.877
2016-04-24	32844244	239336	0.729	16533941	2	0.0	16310303	239334	1.467
2016-04-25	61648530	448352	0.727	27532332	0	0.0	34116198	448352	1.314
2016-04-26	51762664	707678	1.367	23271706	1	0.0	28490958	707677	2.484
2016-04-27	51443095	435634	0.847	22441805	0	0.0	29001290	435634	1.502
2016-04-28	49571047	455708	0.919	21060520	0	0.0	28510527	455708	1.598
2016-04-29	45740028	441684	0.966	19304866	0	0.0	26435162	441684	1.671
2016-04-30	44747668	1917000	4.284	18482843	529918	2.867	26264825	1387082	5.281
2016-05-01	38826732	335504	0.864	16407601	0	0.0	22419131	335504	1.497
2016-05-02	36971583	432736	1.17	15561500	0	0.0	21410083	432736	2.021
2016-05-03	34043783	344360	1.012	14283511	0	0.0	19760272	344360	1.743
2016-05-04	32862327	339706	1.034	14013298	0	0.0	18849029	339706	1.802
2016-05-05	31535242	323076	1.024	13427299	0	0.0	18107943	323076	1.784
2016-05-06	30227071	318780	1.055	12798897	0	0.0	17428174	318780	1.829
2016-05-07	26738540	265672	0.994	11477044	0	0.0	15261496	265672	1.741
2016-05-08	20337761	207420	1.02	8893020	0	0.0	11444741	207420	1.812
2016-05-09	19254690	212336	1.103	8408779	0	0.0	10845911	212336	1.958

Date	Online users online play-backs	Online users offline play-backs	Offline users online play-backs	Offline users offline play-backs	Affected play-backs from albums	Affected play-backs from albums %	Affected online play-backs from albums	Affected offline play-backs from albums
2016-01-21	0	33878	0	24970	0	0.0	0	0
2016-01-22	0	36370	0	27084	0	0.0	0	0
2016-01-23	0	32640	0	23584	0	0.0	0	0
2016-01-24	0	33716	0	21388	0	0.0	0	0
2016-01-25	0	34346	0	24570	0	0.0	0	0
2016-01-26	0	35116	0	22740	0	0.0	0	0
2016-01-27	0	118484	0	57326	0	0.0	0	0
2016-01-28	0	66080	0	28474	0	0.0	0	0
2016-01-29	0	69080	0	33224	0	0.0	0	0
2016-01-30	0	56312	0	33572	0	0.0	0	0
2016-01-31	0	48950	0	29424	0	0.0	0	0
2016-02-01	0	54500	0	36598	0	0.0	0	0
2016-02-02	0	54490	0	37438	0	0.0	0	0
2016-02-03	0	53484	0	36648	0	0.0	0	0
2016-02-04	0	56070	0	40634	0	0.0	0	0
2016-02-05	0	63542	0	38990	0	0.0	0	0
2016-02-06	0	68708	0	37716	0	0.0	0	0
2016-02-07	0	63606	0	26176	0	0.0	0	0
2016-02-08	0	62644	0	26862	0	0.0	0	0
2016-02-09	0	60390	0	34548	0	0.0	0	0
2016-02-10	0	58968	0	35314	0	0.0	0	0
2016-02-11	0	64546	0	38434	0	0.0	0	0
2016-02-12	0	69176	0	33886	0	0.0	0	0
2016-02-13	0	63894	0	35890	0	0.0	0	0
2016-02-14	2850730	2723796	0	540772	4335446	70.895	2020349	2315097
2016-02-15	3053831	2623869	0	1487166	4937780	68.917	2015315	2922465
2016-02-16	2938168	2657648	0	1745752	4780636	65.117	1769607	3011029
2016-02-17	2831421	2605113	0	1893922	4469046	60.965	1537398	2931648
2016-02-18	2640953	2465963	0	1887528	3990740	57.056	1307609	2683131
2016-02-19	2570530	2475424	0	1874814	3694746	53.386	1165928	2528818
2016-02-20	2310437	2220357	0	1630296	3065756	49.76	920394	2145362
2016-02-21	1958538	1797040	0	1391970	2433134	47.268	737798	1695336
2016-02-22	2136875	2147001	0	1446386	2661058	46.439	806081	1854977
2016-02-23	2114657	2181111	0	1416512	2461764	43.096	718301	1743463
2016-02-24	0	121272	0	85374	64172	31.054	0	64172
2016-02-25	0	120010	0	90682	62234	29.538	0	62234
2016-02-26	0	129004	0	88946	60750	27.873	0	60750
2016-02-27	0	111954	0	76280	47036	24.988	0	47036
2016-02-28	0	98810	0	70716	40556	23.923	0	40556
2016-02-29	0	111860	0	77816	52172	27.506	0	52172
2016-03-01	0	114272	0	82850	49746	25.236	0	49746
2016-03-02	0	112806	0	80268	45960	23.804	0	45960
2016-03-03	0	104922	0	76994	42264	23.233	0	42264
2016-04-18	0	97324	0	60626	0	0.0	0	0
2016-04-19	0	98180	0	62404	0	0.0	0	0
2016-04-20	0	121626	0	56358	0	0.0	0	0
2016-04-21	6	105504	0	56272	0	0.0	0	0
2016-04-22	0	120990	0	58934	0	0.0	0	0
2016-04-23	0	95278	0	52134	0	0.0	0	0
2016-04-24	2	194846	0	44488	85528	35.736	2	85526
2016-04-25	0	345322	0	103030	296690	66.173	0	296690
2016-04-26	1	525389	0	182288	526570	74.408	1	526569
2016-04-27	0	301560	0	134074	243360	55.863	0	243360
2016-04-28	0	307510	0	148198	246410	54.072	0	246410
2016-04-29	0	300492	0	141192	223346	50.567	0	223346
2016-04-30	529918	904004	0	483078	1738460	90.686	529918	1208542
2016-05-01	0	213724	0	121780	168930	50.351	0	168930
2016-05-02	0	281466	0	151270	203350	46.992	0	203350
2016-05-03	0	211672	0	132688	133510	38.77	0	133510
2016-05-04	0	208204	0	131502	124288	36.587	0	124288
2016-05-05	0	200344	0	122732	110300	34.141	0	110300
2016-05-06	0	202460	0	116320	90368	28.348	0	90368
2016-05-07	0	170736	0	94936	61690	23.22	0	61690
2016-05-08	0	128888	0	78532	46584	22.459	0	46584
2016-05-09	0	131302	0	81034	44788	21.093	0	44788

Table 7: Two duplicates affected users playbacks

We understand that two identical log entries could be caused by a fault in the system, however we consider three or more duplicate entries to be very unlikely to occur. Table 8 shows that about one percent of all users was normally affected by this impossibility during normal days in the first period, while raising to thirty percent during the suspicious days.

Table 9 show that half a percent of all playbacks during each day was marked as a three or more duplicate. Finally, Table 10 show that these playbacks almost exclusively played tracks from the two albums. This impossible scenario even continues after the ten suspicious days in the first period. Although this scenario affected very few playbacks in the second period, most of those affected playbacks was from tracks from 'Lemonade' by Beyoncé.

Date	Total users	Affected users	Affected users %	Total online users	Affected online users	Affected online users %	Total offline users	Affected offline users	Affected offline users %
2016-01-21	174620	2092	1.198	135221	1336	0.988	39399	756	1.919
2016-01-22	188796	2241	1.187	149491	1454	0.973	39305	787	2.002
2016-01-23	183237	2021	1.103	148330	1330	0.897	34907	691	1.98
2016-01-24	171511	1855	1.082	137257	1224	0.892	34254	631	1.842
2016-01-25	174896	2217	1.268	135543	1423	1.05	39353	794	2.018
2016-01-26	180917	2274	1.257	140482	1441	1.026	40435	833	2.06
2016-01-27	202757	8447	4.166	165342	6089	3.683	37415	2358	6.302
2016-01-28	356158	3795	1.066	307284	2916	0.949	48874	879	1.799
2016-01-29	344910	4207	1.22	277724	3142	1.131	67186	1065	1.585
2016-01-30	324098	3659	1.129	254269	2636	1.037	69829	1023	1.465
2016-01-31	296886	3255	1.096	225798	2230	0.988	71088	1025	1.442
2016-02-01	300715	3527	1.173	222513	2325	1.045	78202	1202	1.537
2016-02-02	300530	3612	1.202	221130	2381	1.077	79400	1231	1.55
2016-02-03	296753	3675	1.238	216748	2391	1.103	80005	1284	1.605
2016-02-04	298583	3772	1.263	217279	2462	1.133	81304	1310	1.611
2016-02-05	312045	3911	1.253	234200	2635	1.125	77845	1276	1.639
2016-02-06	330846	3504	1.059	270729	2524	0.932	60117	980	1.63
2016-02-07	337341	3182	0.943	287555	2368	0.823	49786	814	1.635
2016-02-08	334768	3638	1.087	278546	2718	0.976	56222	920	1.636
2016-02-09	328425	3726	1.135	260760	2576	0.988	67665	1150	1.7
2016-02-10	328089	3598	1.097	257006	2525	0.982	71083	1073	1.51
2016-02-11	355004	3665	1.032	281945	2576	0.914	73059	1089	1.491
2016-02-12	386880	3995	1.033	316405	2836	0.896	70475	1159	1.645
2016-02-13	358217	3572	0.997	291055	2526	0.868	67162	1046	1.557
2016-02-14	691041	236330	34.199	609112	218266	35.833	81929	18064	22.048
2016-02-15	747981	306128	40.927	574979	244031	42.442	173002	62097	35.894
2016-02-16	800171	317865	39.725	585803	243222	41.519	214368	74643	34.82
2016-02-17	815881	316986	38.852	574861	235908	41.037	241020	81078	33.64
2016-02-18	806257	291439	36.147	551943	213094	38.608	254314	78345	30.806
2016-02-19	817275	280498	34.321	556034	204342	36.75	261241	76156	29.152
2016-02-20	787117	239023	30.367	532886	175506	32.935	254231	63517	24.984
2016-02-21	732423	197588	26.977	486737	145476	29.888	245686	52112	21.211
2016-02-22	770746	223205	28.96	533728	168209	31.516	237018	54996	23.203
2016-02-23	764584	221815	29.011	529906	168688	31.834	234678	53127	22.638
2016-02-24	760152	8199	1.079	514411	5357	1.041	245741	2842	1.157
2016-02-25	747083	8107	1.085	496204	5206	1.049	250879	2901	1.156
2016-02-26	764275	8288	1.084	512378	5632	1.099	251897	2656	1.054
2016-02-27	741229	6807	0.918	494773	4538	0.917	246456	2269	0.921
2016-02-28	696194	6162	0.885	459151	4022	0.876	237043	2140	0.903
2016-02-29	691263	7313	1.058	449202	4735	1.054	242061	2578	1.065
2016-03-01	696388	7537	1.082	454878	4804	1.056	241510	2733	1.132
2016-03-02	700917	7179	1.024	461109	4597	0.997	239808	2582	1.077
2016-03-03	691915	7333	1.06	451042	4706	1.043	240873	2627	1.091
2016-04-18	461253	6295	1.365	340662	4602	1.351	120591	1693	1.404
2016-04-19	463153	6359	1.373	343033	4597	1.34	120120	1762	1.467
2016-04-20	504825	6644	1.316	402684	5109	1.269	102141	1535	1.503
2016-04-21	494942	6069	1.226	392501	4616	1.176	102441	1453	1.418
2016-04-22	530312	7199	1.358	429837	5617	1.307	100475	1582	1.575
2016-04-23	500494	5927	1.184	398927	4490	1.126	101567	1437	1.415
2016-04-24	1017351	9819	0.965	937338	8693	0.927	80013	1126	1.407
2016-04-25	1084330	12092	1.115	936931	10101	1.078	147399	1991	1.351
2016-04-26	1106615	13144	1.188	921532	10570	1.147	185083	2574	1.391
2016-04-27	1086552	12549	1.155	878715	9839	1.12	207837	2710	1.304
2016-04-28	1066626	12460	1.168	841933	9714	1.154	224693	2746	1.222
2016-04-29	1079856	12403	1.149	854740	9653	1.129	225116	2750	1.222
2016-04-30	1005141	11665	1.161	778704	8814	1.132	226437	2851	1.259
2016-05-01	922822	8503	0.921	703029	6376	0.907	219793	2127	0.968
2016-05-02	923637	13502	1.462	690843	10135	1.467	232794	3367	1.446
2016-05-03	912692	10173	1.115	668396	7330	1.097	244296	2843	1.164
2016-05-04	919118	10111	1.1	683132	7316	1.071	235986	2795	1.184
2016-05-05	889725	10070	1.132	659028	7411	1.125	230697	2659	1.153
2016-05-06	887489	10291	1.16	658611	7594	1.153	228878	2697	1.178
2016-05-07	851475	8765	1.029	628638	6442	1.025	222837	2323	1.042
2016-05-08	790803	7993	1.011	581512	5882	1.012	209291	2111	1.009
2016-05-09	807714	9267	1.147	590649	6639	1.124	217065	2628	1.211

Table 8: Three or more duplicates system users

Date	Total play-backs	Affected play-backs	Affected play-backs %	Total online play-backs	Affected online play-backs	Affected online play-backs %	Total offline play-backs	Affected offline play-backs	Affected offline play-backs %
2016-01-21	5183365	30416	0.587	2887796	0	0.0	2295569	30416	1.325
2016-01-22	5699857	32780	0.575	3197499	0	0.0	2502358	32780	1.31
2016-01-23	5706073	33559	0.588	3320763	0	0.0	2385310	33559	1.407
2016-01-24	4990937	28291	0.567	2877218	0	0.0	2113719	28291	1.338
2016-01-25	5034490	33240	0.66	2775176	0	0.0	2259314	33240	1.471
2016-01-26	5211451	34479	0.662	2861114	0	0.0	2350337	34479	1.467
2016-01-27	5699874	74644	1.31	3115105	0	0.0	2584769	74644	2.888
2016-01-28	10716712	49834	0.465	5406227	0	0.0	5310485	49834	0.938
2016-01-29	10860619	52553	0.484	5522217	0	0.0	5338402	52553	0.984
2016-01-30	10008250	48992	0.49	5200705	0	0.0	4807545	48992	1.019
2016-01-31	8445037	43832	0.519	4380686	0	0.0	4064351	43832	1.078
2016-02-01	8595181	46009	0.535	4260810	0	0.0	4334371	46009	1.061
2016-02-02	8469929	49782	0.588	4153867	0	0.0	4316062	49782	1.153
2016-02-03	8386787	44969	0.536	4130617	0	0.0	4256170	44969	1.057
2016-02-04	8410214	47370	0.563	4128894	0	0.0	4281320	47370	1.106
2016-02-05	9001255	48487	0.539	4503223	0	0.0	4498032	48487	1.078
2016-02-06	8841003	48479	0.548	4623472	0	0.0	4217531	48479	1.149
2016-02-07	8375341	43932	0.525	4562874	0	0.0	3812467	43932	1.152
2016-02-08	8145940	45992	0.565	4244968	0	0.0	3900972	45992	1.179
2016-02-09	8439985	49478	0.586	4289622	0	0.0	4150363	49478	1.192
2016-02-10	8437553	48640	0.576	4261212	0	0.0	4176341	48640	1.165
2016-02-11	8748323	46608	0.533	4431643	0	0.0	4316680	46608	1.08
2016-02-12	9591865	55185	0.575	4932532	0	0.0	4659333	55185	1.184
2016-02-13	9207400	46770	0.508	4815322	0	0.0	4392078	46770	1.065
2016-02-14	52264508	10690169	20.454	25683182	4934123	19.211	26581326	5756046	21.654
2016-02-15	62315131	15050131	24.152	28423017	6426009	22.608	33892114	8624122	25.446
2016-02-16	62575347	13856459	22.144	27216556	5482933	20.146	35358791	8373526	23.682
2016-02-17	61635277	12920354	20.963	26096222	4965209	19.027	35539055	7955145	22.384
2016-02-18	58176702	11153454	19.172	24279133	4191485	17.264	33897569	6961969	20.538
2016-02-19	57453384	10274083	17.882	23863079	3806219	15.95	33590305	6467864	19.255
2016-02-20	51238240	7808483	15.24	21695419	2927268	13.493	29542821	4881215	16.523
2016-02-21	44012913	6206960	14.103	19017377	2436149	12.81	24995536	3770811	15.086
2016-02-22	48123726	7557730	15.705	20139829	2861974	14.211	27983897	4695756	16.78
2016-02-23	47818784	7258902	15.18	19908725	2723275	13.679	27910059	4535627	16.251
2016-02-24	19205376	83270	0.434	8020004	0	0.0	11185372	83270	0.744
2016-02-25	19155488	88747	0.463	7933048	0	0.0	11222440	88747	0.791
2016-02-26	19895000	85875	0.432	8316062	0	0.0	11578938	85875	0.742
2016-02-27	18410754	75812	0.412	7817765	0	0.0	10592989	75812	0.716
2016-02-28	16341019	69772	0.427	7006815	0	0.0	9334204	69772	0.747
2016-02-29	17041782	76754	0.45	7049968	0	0.0	9991814	76754	0.768
2016-03-01	17519578	81243	0.464	7264171	0	0.0	10255407	81243	0.792
2016-03-02	17260480	73776	0.427	7182545	0	0.0	10077935	73776	0.732
2016-03-03	17326476	82016	0.473	7175051	0	0.0	10151425	82016	0.808
2016-04-18	13094984	79404	0.606	5480281	0	0.0	7614703	79404	1.043
2016-04-19	13228953	78372	0.592	5561693	0	0.0	7667260	78372	1.022
2016-04-20	13716969	79478	0.579	5943181	0	0.0	7773788	79478	1.022
2016-04-21	13592572	76882	0.566	6080560	0	0.0	7512012	76882	1.023
2016-04-22	15716545	90678	0.577	7204431	0	0.0	8512114	90678	1.065
2016-04-23	14539943	73443	0.505	6686559	0	0.0	7853384	73443	0.935
2016-04-24	32844244	117585	0.358	16533941	0	0.0	16310303	117585	0.721
2016-04-25	61648530	199864	0.324	27532332	0	0.0	34116198	199864	0.586
2016-04-26	51762664	200859	0.388	23271706	0	0.0	28490958	200859	0.705
2016-04-27	51443095	207079	0.403	22441805	0	0.0	29001290	207079	0.714
2016-04-28	49571047	207479	0.419	21060520	0	0.0	28510527	207479	0.728
2016-04-29	45740028	207750	0.454	19304866	0	0.0	26435162	207750	0.786
2016-04-30	44747668	186791	0.417	18482843	0	0.0	26264825	186791	0.711
2016-05-01	38826732	152038	0.392	16407601	0	0.0	22419131	152038	0.678
2016-05-02	36971583	184537	0.499	15561500	0	0.0	21410083	184537	0.862
2016-05-03	34043783	173450	0.509	14283511	0	0.0	19760272	173450	0.878
2016-05-04	32862327	159560	0.486	14013298	0	0.0	18849029	159560	0.847
2016-05-05	31535242	154211	0.489	13427299	0	0.0	18107943	154211	0.852
2016-05-06	30227071	156603	0.518	12798897	0	0.0	17428174	156603	0.899
2016-05-07	26738540	122615	0.459	11477044	0	0.0	15261496	122615	0.803
2016-05-08	20337761	101036	0.497	8893020	0	0.0	11444741	101036	0.883
2016-05-09	19254690	111609	0.58	8408779	0	0.0	10845911	111609	1.029

Date	Online users online play-backs	Online users offline play-backs	Offline users online play-backs	Offline users offline play-backs	Affected play-backs from albums	Affected play-backs from albums %	Affected online play-backs from albums	Affected offline play-backs from albums
2016-01-21	0	17598	0	12818	0	0.0	0	0
2016-01-22	0	18372	0	14408	0	0.0	0	0
2016-01-23	0	17779	0	15780	0	0.0	0	0
2016-01-24	0	14928	0	13363	0	0.0	0	0
2016-01-25	0	19185	0	14055	0	0.0	0	0
2016-01-26	0	18234	0	16245	0	0.0	0	0
2016-01-27	0	49982	0	24662	0	0.0	0	0
2016-01-28	0	33523	0	16311	0	0.0	0	0
2016-01-29	0	36236	0	16317	0	0.0	0	0
2016-01-30	0	30667	0	18325	0	0.0	0	0
2016-01-31	0	26044	0	17788	0	0.0	0	0
2016-02-01	0	26963	0	19046	0	0.0	0	0
2016-02-02	0	27969	0	21813	0	0.0	0	0
2016-02-03	0	24848	0	20121	0	0.0	0	0
2016-02-04	0	24972	0	22398	0	0.0	0	0
2016-02-05	0	29593	0	18894	0	0.0	0	0
2016-02-06	0	29382	0	19097	0	0.0	0	0
2016-02-07	0	26963	0	16969	0	0.0	0	0
2016-02-08	0	28126	0	17866	0	0.0	0	0
2016-02-09	0	29378	0	20100	0	0.0	0	0
2016-02-10	0	30090	0	18550	0	0.0	0	0
2016-02-11	0	28201	0	18407	0	0.0	0	0
2016-02-12	0	34506	0	20679	0	0.0	0	0
2016-02-13	0	27848	0	18922	0	0.0	0	0
2016-02-14	4934123	5089845	0	666201	8947906	83.702	4109839	4838067
2016-02-15	6426009	5751868	0	2872254	12720721	84.522	5336664	7384057
2016-02-16	5482933	5301567	0	3071959	11193926	80.785	4248197	6945729
2016-02-17	4965209	4811611	0	3143534	9847623	76.218	3527806	6319817
2016-02-18	4191485	4139640	0	2822329	8016034	71.87	2777285	5238749
2016-02-19	3806219	3817383	0	2650481	6962242	67.765	2345634	4616608
2016-02-20	2927268	2896475	0	1984740	4815761	61.673	1582917	3232844
2016-02-21	2436149	2219096	0	1551715	3514726	56.626	1209407	2305319
2016-02-22	2861974	2928328	0	1767428	4331472	57.312	1459880	2871592
2016-02-23	2723275	2863272	0	1672355	3816074	52.571	1241066	2575008
2016-02-24	0	48917	0	34353	25499	30.622	0	25499
2016-02-25	0	52995	0	35752	24271	27.349	0	24271
2016-02-26	0	51778	0	34097	23480	27.342	0	23480
2016-02-27	0	45369	0	30443	19152	25.262	0	19152
2016-02-28	0	40244	0	29528	16094	23.067	0	16094
2016-02-29	0	45581	0	31173	19153	24.954	0	19153
2016-03-01	0	44969	0	36274	18257	22.472	0	18257
2016-03-02	0	41986	0	31790	17715	24.012	0	17715
2016-03-03	0	44171	0	37845	17613	21.475	0	17613
2016-04-18	0	51483	0	27921	0	0.0	0	0
2016-04-19	0	46763	0	31609	0	0.0	0	0
2016-04-20	0	53819	0	25659	0	0.0	0	0
2016-04-21	0	51787	0	25095	0	0.0	0	0
2016-04-22	0	61888	0	28790	0	0.0	0	0
2016-04-23	0	47083	0	26360	0	0.0	0	0
2016-04-24	0	94811	0	22774	44928	38.209	0	44928
2016-04-25	0	157064	0	42800	119152	59.617	0	119152
2016-04-26	0	147654	0	53205	106938	53.24	0	106938
2016-04-27	0	145923	0	61156	110788	53.5	0	110788
2016-04-28	0	148338	0	59141	108146	52.124	0	108146
2016-04-29	0	146261	0	61489	95668	46.05	0	95668
2016-04-30	0	127097	0	59694	98623	52.799	0	98623
2016-05-01	0	97661	0	54377	68871	45.299	0	68871
2016-05-02	0	121910	0	62627	76510	41.461	0	76510
2016-05-03	0	105968	0	67482	66110	38.115	0	66110
2016-05-04	0	99748	0	59812	54660	34.257	0	54660
2016-05-05	0	100792	0	53419	49314	31.978	0	49314
2016-05-06	0	98660	0	57943	44189	28.217	0	44189
2016-05-07	0	81499	0	41116	28903	23.572	0	28903
2016-05-08	0	64545	0	36491	20781	20.568	0	20781
2016-05-09	0	68468	0	43141	22992	20.6	0	22992

Table 10: Three or more duplicates affected users playbacks

Identical duplicates can occur due to a fault in the system. There are several potential reasons for this, such as cache fault and poor design and implementation. However, *unequal* duplicates should almost never occur in the logs. With a possible exception in log entries received from devices with weird timestamps. Which means that occurrences from this impossible scenario should be low.

Two unequal duplicates means that two playbacks has the identical timestamp and system user ID, while differing in track IDs. The results in Table 11 show that this was normally an infrequent occurrence, with the exception of two suspicious periods. Table 12 and 13 continues to demonstrate that a lot of users and playbacks was affected by this scenario in those suspicious periods.

Date	Total users	Affected users	Affected users %	Total online users	Affected online users	Affected online users %	Total offline users	Affected offline users	Affected offline users %
2016-01-21	174620	366	0.21	135221	226	0.167	39399	140	0.355
2016-01-22	188796	361	0.191	149491	243	0.163	39305	118	0.3
2016-01-23	183237	361	0.197	148330	244	0.164	34907	117	0.335
2016-01-24	171511	288	0.168	137257	190	0.138	34254	98	0.286
2016-01-25	174896	332	0.19	135543	198	0.146	39353	134	0.341
2016-01-26	180917	338	0.187	140482	212	0.151	40435	126	0.312
2016-01-27	202757	354	0.175	165342	221	0.134	37415	133	0.355
2016-01-28	356158	419	0.118	307284	279	0.091	48874	140	0.286
2016-01-29	344910	438	0.127	277724	301	0.108	67186	137	0.204
2016-01-30	324098	398	0.123	254269	275	0.108	69829	123	0.176
2016-01-31	296886	334	0.113	225798	223	0.099	71088	111	0.156
2016-02-01	300715	348	0.116	222513	207	0.093	78202	141	0.18
2016-02-02	300530	378	0.126	221130	229	0.104	79400	149	0.188
2016-02-03	296753	343	0.116	216748	192	0.089	80005	151	0.189
2016-02-04	298583	383	0.128	217279	247	0.114	81304	136	0.167
2016-02-05	312045	404	0.129	234200	265	0.113	77845	139	0.179
2016-02-06	330846	377	0.114	270729	267	0.099	60117	110	0.183
2016-02-07	337341	327	0.097	287555	214	0.074	49786	113	0.227
2016-02-08	334768	365	0.109	278546	237	0.085	56222	128	0.228
2016-02-09	328425	315	0.096	260760	210	0.081	67665	105	0.155
2016-02-10	328089	372	0.113	257006	228	0.089	71083	144	0.203
2016-02-11	355004	344	0.097	281945	220	0.078	73059	124	0.17
2016-02-12	386880	392	0.101	316405	267	0.084	70475	125	0.177
2016-02-13	358217	342	0.095	291055	240	0.082	67162	102	0.152
2016-02-14	691041	25557	3.698	609112	20396	3.348	81929	5161	6.299
2016-02-15	747981	25678	3.433	574979	17189	2.99	173002	8489	4.907
2016-02-16	800171	31011	3.876	585803	19593	3.345	214368	11418	5.326
2016-02-17	815881	33157	4.064	574861	19563	3.403	241020	13594	5.64
2016-02-18	806257	35677	4.425	551943	20447	3.705	254314	15230	5.989
2016-02-19	817275	37451	4.582	556034	21025	3.781	261241	16426	6.288
2016-02-20	787117	39784	5.054	532886	22463	4.215	254231	17321	6.813
2016-02-21	732423	39207	5.353	486737	21418	4.4	245686	17789	7.241
2016-02-22	770746	38176	4.953	533728	22217	4.163	237018	15959	6.733
2016-02-23	764584	40351	5.278	529906	23721	4.476	234678	16630	7.086
2016-02-24	760152	515	0.068	514411	363	0.071	245741	152	0.062
2016-02-25	747083	515	0.069	496204	374	0.075	250879	141	0.056
2016-02-26	764275	563	0.074	512378	419	0.082	251897	144	0.057
2016-02-27	741229	496	0.067	494773	370	0.075	246456	126	0.051
2016-02-28	696194	434	0.062	459151	293	0.064	237043	141	0.059
2016-02-29	691263	517	0.075	449202	353	0.079	242061	164	0.068
2016-03-01	696388	504	0.072	454878	362	0.08	241510	142	0.059
2016-03-02	700917	486	0.069	461109	336	0.073	239808	150	0.063
2016-03-03	691915	544	0.079	451042	386	0.086	240873	158	0.066
2016-04-18	461253	370	0.08	340662	271	0.08	120591	99	0.082
2016-04-19	463153	383	0.083	343033	275	0.08	120120	108	0.09
2016-04-20	504825	395	0.078	402684	296	0.074	102141	99	0.097
2016-04-21	494942	384	0.078	392501	290	0.074	102441	94	0.092
2016-04-22	530312	455	0.086	429837	345	0.08	100475	110	0.109
2016-04-23	500494	375	0.075	398927	294	0.074	101567	81	0.08
2016-04-24	1017351	1787	0.176	937338	1661	0.177	80013	126	0.157
2016-04-25	1084330	11416	1.053	936931	9331	0.996	147399	2085	1.415
2016-04-26	1106615	7617	0.688	921532	5910	0.641	185083	1707	0.922
2016-04-27	1086552	6707	0.617	878715	4958	0.564	207837	1749	0.842
2016-04-28	1066626	6444	0.604	841933	4668	0.554	224693	1776	0.79
2016-04-29	1079856	4694	0.435	854740	3373	0.395	225116	1321	0.587
2016-04-30	1005141	5881	0.585	778704	4064	0.522	226437	1817	0.802
2016-05-01	922822	5434	0.589	703029	3758	0.535	219793	1676	0.763
2016-05-02	923637	3573	0.387	690843	2545	0.368	232794	1028	0.442
2016-05-03	912692	2592	0.284	668396	1783	0.267	244296	809	0.331
2016-05-04	919118	2396	0.261	683132	1687	0.247	235986	709	0.3
2016-05-05	889725	2388	0.268	659028	1725	0.262	230697	663	0.287
2016-05-06	887489	1972	0.222	658611	1431	0.217	228878	541	0.236
2016-05-07	851475	1671	0.196	628638	1239	0.197	222837	432	0.194
2016-05-08	790803	791	0.1	581512	576	0.099	209291	215	0.103
2016-05-09	807714	381	0.047	590649	293	0.05	217065	88	0.041

Table 11: Two unequal duplicates system users

Date	Total play-backs	Affected play-backs	Affected play-backs %	Total online play-backs	Affected online play-backs	Affected online play-backs %	Total offline play-backs	Affected offline play-backs	Affected offline play-backs %
2016-01-21	5183365	762	0.015	2887796	2	0.0	2295569	760	0.033
2016-01-22	5699857	740	0.013	3197499	3	0.0	2502358	737	0.029
2016-01-23	5706073	734	0.013	3320763	7	0.0	2385310	727	0.03
2016-01-24	4990937	588	0.012	2877218	2	0.0	2113719	586	0.028
2016-01-25	5034490	682	0.014	2775176	2	0.0	2259314	680	0.03
2016-01-26	5211451	694	0.013	2861114	3	0.0	2350337	691	0.029
2016-01-27	5699874	728	0.013	3115105	2	0.0	2584769	726	0.028
2016-01-28	10716712	866	0.008	5406227	4	0.0	5310485	862	0.016
2016-01-29	10860619	908	0.008	5522217	5	0.0	5338402	903	0.017
2016-01-30	10008250	824	0.008	5200705	6	0.0	4807545	818	0.017
2016-01-31	8445037	688	0.008	4380686	6	0.0	4064351	682	0.017
2016-02-01	8595181	716	0.008	4260810	1	0.0	4334371	715	0.016
2016-02-02	8469929	786	0.009	4153867	4	0.0	4316062	782	0.018
2016-02-03	8386787	708	0.008	4130617	3	0.0	4256170	705	0.017
2016-02-04	8410214	794	0.009	4128894	5	0.0	4281320	789	0.018
2016-02-05	9001255	830	0.009	4503223	2	0.0	4498032	828	0.018
2016-02-06	8841003	776	0.009	4623472	5	0.0	4217531	771	0.018
2016-02-07	8375341	666	0.008	4562874	3	0.0	3812467	663	0.017
2016-02-08	8145940	762	0.009	4244968	10	0.0	3900972	752	0.019
2016-02-09	8439985	642	0.008	4289622	6	0.0	4150363	636	0.015
2016-02-10	8437553	758	0.009	4261212	4	0.0	4176341	754	0.018
2016-02-11	8748323	726	0.008	4431643	2	0.0	4316680	724	0.017
2016-02-12	9591865	804	0.008	4932532	8	0.0	4659333	796	0.017
2016-02-13	9207400	712	0.008	4815322	5	0.0	4392078	707	0.016
2016-02-14	52264508	88234	0.169	25683182	53560	0.209	26581326	34674	0.13
2016-02-15	62315131	102684	0.165	28423017	48191	0.17	33892114	54493	0.161
2016-02-16	62575347	123824	0.198	27216556	54760	0.201	35358791	69064	0.195
2016-02-17	61635277	132694	0.215	26096222	52583	0.201	35539055	80111	0.225
2016-02-18	58176702	143182	0.246	24279133	54412	0.224	33897569	88770	0.262
2016-02-19	57453384	150192	0.261	23863079	55431	0.232	33590305	94761	0.282
2016-02-20	51238240	160064	0.312	21695419	61596	0.284	29542821	98468	0.333
2016-02-21	44012913	157886	0.359	19017377	60271	0.317	24995536	97615	0.391
2016-02-22	48123726	153564	0.319	20139829	61372	0.305	27983897	92192	0.329
2016-02-23	47818784	162250	0.339	19908725	66228	0.333	27910059	96022	0.344
2016-02-24	19205376	1078	0.006	8020004	5	0.0	11185372	1073	0.01
2016-02-25	19155488	1064	0.006	7933048	4	0.0	11222440	1060	0.009
2016-02-26	19895000	1172	0.006	8316062	8	0.0	11578938	1164	0.01
2016-02-27	18410754	1060	0.006	7817765	10	0.0	10592989	1050	0.01
2016-02-28	16341019	898	0.005	7006815	6	0.0	9334204	892	0.01
2016-02-29	17041782	1080	0.006	7049968	9	0.0	9991814	1071	0.011
2016-03-01	17519578	1046	0.006	7264171	6	0.0	10255407	1040	0.01
2016-03-02	17260480	1024	0.006	7182545	9	0.0	10077935	1015	0.01
2016-03-03	17326476	1140	0.007	7175051	9	0.0	10151425	1131	0.011
2016-04-18	13094984	762	0.006	5480281	6	0.0	7614703	756	0.01
2016-04-19	13228953	804	0.006	5561693	5	0.0	7667260	799	0.01
2016-04-20	13716969	828	0.006	5943181	8	0.0	7773788	820	0.011
2016-04-21	13592572	816	0.006	6080560	5	0.0	7512012	811	0.011
2016-04-22	15716545	948	0.006	7204431	10	0.0	8512114	938	0.011
2016-04-23	14539943	780	0.005	6686559	8	0.0	7853384	772	0.01
2016-04-24	32844244	3950	0.012	16533941	22	0.0	16310303	3928	0.024
2016-04-25	61648530	39340	0.064	27532332	22	0.0	34116198	39318	0.115
2016-04-26	51762664	26660	0.052	23271706	32	0.0	28490958	26628	0.093
2016-04-27	51443095	16640	0.032	22441805	15	0.0	29001290	16625	0.057
2016-04-28	49571047	16518	0.033	21060520	23	0.0	28510527	16495	0.058
2016-04-29	45740028	11464	0.025	19304866	36	0.0	26435162	11428	0.043
2016-04-30	44747668	22174	0.05	18482843	45	0.0	26264825	22129	0.084
2016-05-01	38826732	13302	0.034	16407601	32	0.0	22419131	13270	0.059
2016-05-02	36971583	8526	0.023	15561500	15	0.0	21410083	8511	0.04
2016-05-03	34043783	6404	0.019	14283511	18	0.0	19760272	6386	0.032
2016-05-04	32862327	5786	0.018	14013298	22	0.0	18849029	5764	0.031
2016-05-05	31535242	5688	0.018	13427299	15	0.0	18107943	5673	0.031
2016-05-06	30227071	4812	0.016	12798897	11	0.0	17428174	4801	0.028
2016-05-07	26738540	3914	0.015	11477044	22	0.0	15261496	3892	0.026
2016-05-08	20337761	1782	0.009	8893020	15	0.0	11444741	1767	0.015
2016-05-09	19254690	792	0.004	8408779	12	0.0	10845911	780	0.007

Date	Online users online play-backs	Online users offline play-backs	Offline users online play-backs	Offline users offline play-backs	Affected play-backs from albums	Affected play-backs from albums %	Affected online play-backs from albums	Affected offline play-backs from albums
2016-01-21	2	468	0	292	0	0.0	0	0
2016-01-22	3	491	0	246	0	0.0	0	0
2016-01-23	7	487	0	240	0	0.0	0	0
2016-01-24	2	388	0	198	0	0.0	0	0
2016-01-25	2	408	0	272	0	0.0	0	0
2016-01-26	3	429	0	262	0	0.0	0	0
2016-01-27	2	448	0	278	0	0.0	0	0
2016-01-28	4	574	0	288	0	0.0	0	0
2016-01-29	5	617	0	286	0	0.0	0	0
2016-01-30	6	560	0	258	0	0.0	0	0
2016-01-31	6	454	0	228	0	0.0	0	0
2016-02-01	1	425	0	290	0	0.0	0	0
2016-02-02	4	472	0	310	0	0.0	0	0
2016-02-03	3	401	0	304	0	0.0	0	0
2016-02-04	5	505	0	284	0	0.0	0	0
2016-02-05	2	536	0	292	0	0.0	0	0
2016-02-06	5	541	0	230	0	0.0	0	0
2016-02-07	3	429	0	234	0	0.0	0	0
2016-02-08	10	488	0	264	0	0.0	0	0
2016-02-09	6	422	0	214	0	0.0	0	0
2016-02-10	4	456	0	298	0	0.0	0	0
2016-02-11	2	470	0	254	0	0.0	0	0
2016-02-12	8	540	0	256	0	0.0	0	0
2016-02-13	5	497	0	210	0	0.0	0	0
2016-02-14	53560	16644	0	18030	31147	35.3	23580	7567
2016-02-15	48191	20135	0	34358	45415	44.228	18873	26542
2016-02-16	54760	22974	0	46090	59052	47.69	21140	37912
2016-02-17	52583	25161	0	54950	65453	49.326	19624	45829
2016-02-18	54412	27054	0	61716	72195	50.422	20400	51795
2016-02-19	55431	28275	0	66486	74058	49.309	19091	54967
2016-02-20	61596	28232	0	70236	78269	48.899	19757	58512
2016-02-21	60271	25417	0	72198	77779	49.263	19471	58308
2016-02-22	61372	27364	0	64828	70706	46.043	17608	53098
2016-02-23	66228	28494	0	67528	70589	43.506	16530	54059
2016-02-24	5	761	0	312	334	30.983	2	332
2016-02-25	4	776	0	284	292	27.444	0	292
2016-02-26	8	862	0	302	333	28.413	2	331
2016-02-27	10	780	0	270	203	19.151	0	203
2016-02-28	6	606	0	286	201	22.383	1	200
2016-02-29	9	729	0	342	214	19.815	1	213
2016-03-01	6	748	0	292	228	21.797	0	228
2016-03-02	9	709	0	306	241	23.535	0	241
2016-03-03	9	807	0	324	277	24.298	0	277
2016-04-18	6	554	0	202	0	0.0	0	0
2016-04-19	5	573	0	226	0	0.0	0	0
2016-04-20	8	614	0	206	0	0.0	0	0
2016-04-21	5	615	0	196	0	0.0	0	0
2016-04-22	10	714	0	224	0	0.0	0	0
2016-04-23	8	604	0	168	0	0.0	0	0
2016-04-24	22	3660	0	268	2965	75.063	12	2953
2016-04-25	22	32496	0	6822	37288	94.784	13	37275
2016-04-26	32	20740	0	5888	22307	83.672	17	22290
2016-04-27	15	12375	0	4250	12523	75.258	2	12521
2016-04-28	23	12029	0	4466	11550	69.924	7	11543
2016-04-29	36	8224	0	3204	7749	67.594	15	7734
2016-04-30	45	15521	0	6608	19255	86.836	19	19236
2016-05-01	32	9182	0	4088	8456	63.569	3	8453
2016-05-02	15	6119	0	2392	4990	58.527	2	4988
2016-05-03	18	4348	0	2038	2710	42.317	0	2710
2016-05-04	22	4058	0	1706	2295	39.665	4	2291
2016-05-05	15	4047	0	1626	2030	35.689	1	2029
2016-05-06	11	3453	0	1348	1205	25.042	0	1205
2016-05-07	22	2840	0	1052	548	14.001	0	548
2016-05-08	15	1273	0	494	286	16.049	0	286
2016-05-09	12	598	0	182	106	13.384	0	106

Table 13: Two unequal duplicates affected users playbacks

Three or more unequal duplicates should also never really occur in a log system. However, Table 14 illustrate that this was not an infrequent occurrence during the suspicious days. About eighty percent of the users was affected by this impossibility in the days between 2016-02-14 and 2016-02-23. While only affecting a small percentage of system users during the second period, many of those playbacks was from Beyoncé's album.

Table 15 show that about sixty percent of all playbacks during the first suspicious period was a three or more *unequal* duplicate, most of them apparently playing tracks from Kanye's album.

Date	Total users	Affected users	Affected users %	Total online users	Affected online users	Affected online users %	Total offline users	Affected offline users	Affected offline users %
2016-01-21	174620	2939	1.683	135221	1745	1.29	39399	1194	3.031
2016-01-22	188796	3291	1.743	149491	1997	1.336	39305	1294	3.292
2016-01-23	183237	3166	1.728	148330	1981	1.336	34907	1185	3.395
2016-01-24	171511	2884	1.682	137257	1730	1.26	34254	1154	3.369
2016-01-25	174896	2851	1.63	135543	1584	1.169	39353	1267	3.22
2016-01-26	180917	2951	1.631	140482	1676	1.193	40435	1275	3.153
2016-01-27	202757	2939	1.45	165342	1745	1.055	37415	1194	3.191
2016-01-28	356158	3293	0.925	307284	2072	0.674	48874	1221	2.498
2016-01-29	344910	3462	1.004	277724	2167	0.78	67186	1295	1.927
2016-01-30	324098	3437	1.06	254269	2272	0.894	69829	1165	1.668
2016-01-31	296886	3027	1.02	225798	1895	0.839	71088	1132	1.592
2016-02-01	300715	2960	0.984	222513	1760	0.791	78202	1200	1.534
2016-02-02	300530	2967	0.987	221130	1751	0.792	79400	1216	1.531
2016-02-03	296753	3015	1.016	216748	1768	0.816	80005	1247	1.559
2016-02-04	298583	3063	1.026	217279	1787	0.822	81304	1276	1.569
2016-02-05	312045	3226	1.034	234200	2010	0.858	77845	1216	1.562
2016-02-06	330846	3071	0.928	270729	2024	0.748	60117	1047	1.742
2016-02-07	337341	2874	0.852	287555	1839	0.64	49786	1035	2.079
2016-02-08	334768	2731	0.816	278546	1599	0.574	56222	1132	2.013
2016-02-09	328425	2820	0.859	260760	1710	0.656	67665	1110	1.64
2016-02-10	328089	2787	0.849	257006	1670	0.65	71083	1117	1.571
2016-02-11	355004	2858	0.805	281945	1738	0.616	73059	1120	1.533
2016-02-12	386880	3054	0.789	316405	1916	0.606	70475	1138	1.615
2016-02-13	358217	2991	0.835	291055	1923	0.661	67162	1068	1.59
2016-02-14	691041	514378	74.435	609112	455546	74.789	81929	58832	71.809
2016-02-15	747981	597572	79.891	574979	460063	80.014	173002	137509	79.484
2016-02-16	800171	642455	80.29	585803	473033	80.75	214368	169422	79.033
2016-02-17	815881	653053	80.043	574861	463186	80.574	241020	189867	78.776
2016-02-18	806257	639553	79.324	551943	443794	80.406	254314	195759	76.975
2016-02-19	817275	642100	78.566	556034	443885	79.831	261241	198215	75.874
2016-02-20	787117	607544	77.186	532886	421392	79.077	254231	186152	73.222
2016-02-21	732423	549109	74.972	486737	376486	77.349	245686	172623	70.262
2016-02-22	770746	573237	74.374	533728	402110	75.34	237018	171127	72.2
2016-02-23	764584	577685	75.555	529906	408250	77.042	234678	169435	72.199
2016-02-24	760152	3040	0.4	514411	1772	0.344	245741	1268	0.516
2016-02-25	747083	3067	0.411	496204	1809	0.365	250879	1258	0.501
2016-02-26	764275	3200	0.419	512378	1981	0.387	251897	1219	0.484
2016-02-27	741229	3048	0.411	494773	1948	0.394	246456	1100	0.446
2016-02-28	696194	2810	0.404	459151	1746	0.38	237043	1064	0.449
2016-02-29	691263	2796	0.404	449202	1618	0.36	242061	1178	0.487
2016-03-01	696388	2882	0.414	454878	1744	0.383	241510	1138	0.471
2016-03-02	700917	2793	0.398	461109	1657	0.359	239808	1136	0.474
2016-03-03	691915	2869	0.415	451042	1640	0.364	240873	1229	0.51
2016-04-18	461253	2048	0.444	340662	1184	0.348	120591	864	0.716
2016-04-19	463153	2091	0.451	343033	1195	0.348	120120	896	0.746
2016-04-20	504825	2087	0.413	402684	1259	0.313	102141	828	0.811
2016-04-21	494942	2119	0.428	392501	1319	0.336	102441	800	0.781
2016-04-22	530312	2322	0.438	429837	1549	0.36	100475	773	0.769
2016-04-23	500494	2207	0.441	398927	1461	0.366	101567	746	0.734
2016-04-24	1017351	2300	0.226	937338	1672	0.178	80013	628	0.785
2016-04-25	1084330	2602	0.24	936931	1792	0.191	147399	810	0.55
2016-04-26	1106615	2858	0.258	921532	1977	0.215	185083	881	0.476
2016-04-27	1086552	2547	0.234	878715	1627	0.185	207837	920	0.443
2016-04-28	1066626	2637	0.247	841933	1697	0.202	224693	940	0.418
2016-04-29	1079856	2661	0.246	854740	1749	0.205	225116	912	0.405
2016-04-30	1005141	2906	0.289	778704	1935	0.248	226437	971	0.429
2016-05-01	922822	2269	0.246	703029	1454	0.207	219793	815	0.371
2016-05-02	923637	2261	0.245	690843	1387	0.201	232794	874	0.375
2016-05-03	912692	2242	0.246	668396	1338	0.2	244296	904	0.37
2016-05-04	919118	2325	0.253	683132	1416	0.207	235986	909	0.385
2016-05-05	889725	2199	0.247	659028	1405	0.213	230697	794	0.344
2016-05-06	887489	2276	0.256	658611	1453	0.221	228878	823	0.36
2016-05-07	851475	2194	0.258	628638	1405	0.223	222837	789	0.354
2016-05-08	790803	2014	0.255	581512	1248	0.215	209291	766	0.366
2016-05-09	807714	2044	0.253	590649	1228	0.208	217065	816	0.376

Table 14: Three or more unequal duplicates system users

Date	Total play-backs	Affected play-backs	Affected play-backs %	Total online play-backs	Affected online play-backs	Affected online play-backs %	Total offline play-backs	Affected offline play-backs	Affected offline play-backs %
2016-01-21	5183365	70225	1.355	2887796	0	0.0	2295569	70225	3.059
2016-01-22	5699857	77283	1.356	3197499	0	0.0	2502358	77283	3.088
2016-01-23	5706073	80176	1.405	3320763	0	0.0	2385310	80176	3.361
2016-01-24	4990937	66852	1.339	2877218	0	0.0	2113719	66852	3.163
2016-01-25	5034490	68512	1.361	2775176	0	0.0	2259314	68512	3.032
2016-01-26	5211451	68171	1.308	2861114	0	0.0	2350337	68171	2.9
2016-01-27	5699874	71507	1.255	3115105	0	0.0	2584769	71507	2.766
2016-01-28	10716712	80707	0.753	5406227	0	0.0	5310485	80707	1.52
2016-01-29	10860619	85317	0.786	5522217	0	0.0	5338402	85317	1.598
2016-01-30	10008250	90035	0.9	5200705	0	0.0	4807545	90035	1.873
2016-01-31	8445037	73677	0.872	4380686	0	0.0	4064351	73677	1.813
2016-02-01	8595181	69900	0.813	4260810	0	0.0	4334371	69900	1.613
2016-02-02	8469929	67746	0.8	4153867	0	0.0	4316062	67746	1.57
2016-02-03	8386787	68447	0.816	4130617	0	0.0	4256170	68447	1.608
2016-02-04	8410214	72667	0.864	4128894	0	0.0	4281320	72667	1.697
2016-02-05	9001255	80069	0.89	4503223	0	0.0	4498032	80069	1.78
2016-02-06	8841003	80824	0.914	4623472	0	0.0	4217531	80824	1.916
2016-02-07	8375341	69299	0.827	4562874	0	0.0	3812467	69299	1.818
2016-02-08	8145940	62315	0.765	4244968	0	0.0	3900972	62315	1.597
2016-02-09	8439985	67575	0.801	4289622	0	0.0	4150363	67575	1.628
2016-02-10	8437553	65934	0.781	4261212	0	0.0	4176341	65934	1.579
2016-02-11	8748323	69558	0.795	4431643	0	0.0	4316680	69558	1.611
2016-02-12	9591865	74365	0.775	4932532	0	0.0	4659333	74365	1.596
2016-02-13	9207400	78950	0.857	4815322	0	0.0	4392078	78950	1.798
2016-02-14	52264508	28579867	54.683	25683182	13997322	54.5	26581326	14582545	54.86
2016-02-15	62315131	35837686	57.51	28423017	16318023	57.411	33892114	19519663	57.594
2016-02-16	62575347	36141565	57.757	27216556	15689865	57.648	35358791	20451700	57.84
2016-02-17	61635277	35772188	58.038	26096222	15099751	57.862	35539055	20672437	58.168
2016-02-18	58176702	33716728	57.956	24279133	14032095	57.795	33897569	19684633	58.071
2016-02-19	57453384	33290893	57.944	23863079	13778875	57.741	33590305	19512018	58.088
2016-02-20	51238240	29722290	58.008	21695419	12543292	57.815	29542821	17178998	58.149
2016-02-21	44012913	25462084	57.851	19017377	10983059	57.753	24995536	14479025	57.926
2016-02-22	48123726	27815608	57.8	20139829	11565797	57.427	27983897	16249811	58.068
2016-02-23	47818784	27834973	58.209	19908725	11529780	57.913	27910059	16305193	58.42
2016-02-24	19205376	74641	0.389	8020004	0	0.0	11185372	74641	0.667
2016-02-25	19155488	82384	0.43	7933048	0	0.0	11222440	82384	0.734
2016-02-26	19895000	80020	0.402	8316062	0	0.0	11578938	80020	0.691
2016-02-27	18410754	81353	0.442	7817765	0	0.0	10592989	81353	0.768
2016-02-28	16341019	73829	0.452	7006815	0	0.0	9334204	73829	0.791
2016-02-29	17041782	69102	0.405	7049968	0	0.0	9991814	69102	0.692
2016-03-01	17519578	71552	0.408	7264171	0	0.0	10255407	71552	0.698
2016-03-02	17260480	68163	0.395	7182545	1	0.0	10077935	68162	0.676
2016-03-03	17326476	69478	0.401	7175051	0	0.0	10151425	69478	0.684
2016-04-18	13094984	55019	0.42	5480281	0	0.0	7614703	55019	0.723
2016-04-19	13228953	52600	0.398	5561693	0	0.0	7667260	52600	0.686
2016-04-20	13716969	54451	0.397	5943181	0	0.0	7773788	54451	0.7
2016-04-21	13592572	54086	0.398	6080560	0	0.0	7512012	54086	0.72
2016-04-22	15716545	60662	0.386	7204431	0	0.0	8512114	60662	0.713
2016-04-23	14539943	57355	0.394	6686559	0	0.0	7853384	57355	0.73
2016-04-24	32844244	63288	0.193	16533941	0	0.0	16310303	63288	0.388
2016-04-25	61648530	89955	0.146	27532332	0	0.0	34116198	89955	0.264
2016-04-26	51762664	86455	0.167	23271706	0	0.0	28490958	86455	0.303
2016-04-27	51443095	85111	0.165	22441805	0	0.0	29001290	85111	0.293
2016-04-28	49571047	88136	0.178	21060520	0	0.0	28510527	88136	0.309
2016-04-29	45740028	89346	0.195	19304866	0	0.0	26435162	89346	0.338
2016-04-30	44747668	86771	0.194	18482843	0	0.0	26264825	86771	0.33
2016-05-01	38826732	73514	0.189	16407601	0	0.0	22419131	73514	0.328
2016-05-02	36971583	79715	0.216	15561500	0	0.0	21410083	79715	0.372
2016-05-03	34043783	74078	0.218	14283511	0	0.0	19760272	74078	0.375
2016-05-04	32862327	76266	0.232	14013298	0	0.0	18849029	76266	0.405
2016-05-05	31535242	76458	0.242	13427299	0	0.0	18107943	76458	0.422
2016-05-06	30227071	81452	0.269	12798897	0	0.0	17428174	81452	0.467
2016-05-07	26738540	72107	0.27	11477044	0	0.0	15261496	72107	0.472
2016-05-08	20337761	54173	0.266	8893020	1	0.0	11444741	54172	0.473
2016-05-09	19254690	53743	0.279	8408779	0	0.0	10845911	53743	0.496

Date	Online users online play-backs	Online users offline play-backs	Offline users online play-backs	Offline users offline play-backs	Affected play-backs from albums	Affected play-backs from albums %	Affected online play-backs from albums	Affected offline play-backs from albums
2016-01-21	0	40792	0	29433	0	0.0	0	0
2016-01-22	0	45686	0	31597	0	0.0	0	0
2016-01-23	0	49146	0	31030	0	0.0	0	0
2016-01-24	0	40752	0	26100	0	0.0	0	0
2016-01-25	0	40051	0	28461	0	0.0	0	0
2016-01-26	0	39157	0	29014	0	0.0	0	0
2016-01-27	0	43231	0	28276	0	0.0	0	0
2016-01-28	0	51278	0	29429	0	0.0	0	0
2016-01-29	0	55710	0	29607	0	0.0	0	0
2016-01-30	0	58679	0	31356	0	0.0	0	0
2016-01-31	0	47185	0	26492	0	0.0	0	0
2016-02-01	0	42275	0	27625	0	0.0	0	0
2016-02-02	0	40484	0	27262	0	0.0	0	0
2016-02-03	0	39070	0	29377	0	0.0	0	0
2016-02-04	0	42004	0	30663	0	0.0	0	0
2016-02-05	0	51289	0	28780	0	0.0	0	0
2016-02-06	0	52715	0	28109	0	0.0	0	0
2016-02-07	0	43237	0	26062	0	0.0	0	0
2016-02-08	0	36257	0	26058	0	0.0	0	0
2016-02-09	0	41904	0	25671	0	0.0	0	0
2016-02-10	0	41085	0	24849	0	0.0	0	0
2016-02-11	0	41312	0	28246	0	0.0	0	0
2016-02-12	0	44850	0	29515	0	0.0	0	0
2016-02-13	0	50821	0	28129	0	0.0	0	0
2016-02-14	13997322	12149039	0	2433506	18098334	63.325	8489026	9609308
2016-02-15	16318023	12805452	0	6714211	22864291	63.8	9571626	13292665
2016-02-16	15689865	12800603	0	7651097	21369275	59.127	8121398	13247877
2016-02-17	15099751	12442672	0	8229765	19528939	54.593	6951392	12577547
2016-02-18	14032095	11665625	0	8019008	16902330	50.13	5754559	11147771
2016-02-19	13778875	11600967	0	7911051	15358269	46.134	5045641	10312628
2016-02-20	12543292	10340512	0	6838486	12213349	41.092	3823100	8390249
2016-02-21	10983059	8543361	0	5935664	9720085	38.175	3087757	6632328
2016-02-22	11565797	10020916	0	6228895	10917131	39.248	3469908	7447223
2016-02-23	11529780	10191228	0	6113965	10020697	36.0	3072840	6947857
2016-02-24	0	43793	0	30848	10314	13.818	0	10314
2016-02-25	0	50016	0	32368	10464	12.701	0	10464
2016-02-26	0	50447	0	29573	9925	12.403	0	9925
2016-02-27	0	51983	0	29370	8890	10.928	0	8890
2016-02-28	0	45053	0	28776	7347	9.951	0	7347
2016-02-29	0	40090	0	29012	8432	12.202	0	8432
2016-03-01	0	41522	0	30030	7184	10.04	0	7184
2016-03-02	1	39429	0	28733	6859	10.063	1	6858
2016-03-03	0	38644	0	30834	6586	9.479	0	6586
2016-04-18	0	31672	0	23347	0	0.0	0	0
2016-04-19	0	29671	0	22929	0	0.0	0	0
2016-04-20	0	32864	0	21587	0	0.0	0	0
2016-04-21	0	34060	0	20026	0	0.0	0	0
2016-04-22	0	42045	0	18617	0	0.0	0	0
2016-04-23	0	37293	0	20062	0	0.0	0	0
2016-04-24	0	45059	0	18229	15971	25.235	0	15971
2016-04-25	0	64701	0	25254	40563	45.093	0	40563
2016-04-26	0	60337	0	26118	27330	31.612	0	27330
2016-04-27	0	55496	0	29615	28178	33.107	0	28178
2016-04-28	0	57218	0	30918	27534	31.24	0	27534
2016-04-29	0	58370	0	30976	21940	24.556	0	21940
2016-04-30	0	56992	0	29779	26341	30.357	0	26341
2016-05-01	0	47346	0	26168	20727	28.195	0	20727
2016-05-02	0	47712	0	32003	18467	23.166	0	18467
2016-05-03	0	43154	0	30924	13218	17.843	0	13218
2016-05-04	0	45868	0	30398	12745	16.711	0	12745
2016-05-05	0	48948	0	27510	10815	14.145	0	10815
2016-05-06	0	51520	0	29932	9950	12.216	0	9950
2016-05-07	0	46388	0	25719	7451	10.333	0	7451
2016-05-08	1	33446	0	20726	3843	7.094	0	3843
2016-05-09	0	31643	0	22100	4802	8.935	0	4802

Table 16: Three or more unequal duplicates affected users playbacks

5.9 Modulo six findings

The previous tables show that users in the first period are most affected by impossibilities which are described in analysis method 2 (Subsection 4.2) than users in the second period. Dagens Næringsliv have on their own inspected a tiny subset of users in the second period, and identified a high count of playbacks which ends on the same second and milliseconds. They suspect that legitimate playbacks have been duplicated by changing the hours and minutes of original playbacks. The amount of change in the timestamp appears to always be evenly divided by six minutes.

It is statistically possible for users to play one track ID on two different timestamps which end on the same seconds and milliseconds, and those two timestamps being divisible by six minutes. Table 17 show that around one percent was affected by this scenario in normal days. A closer inspection of the affected playbacks for normal days confirms our suspicion that they are caused by devices with inadequate ability to record milliseconds. As all the records have '.000' as milliseconds. However, during the second suspicious period, this scenario started to also affect records with all types of millisecond numbers. It is an extremely rare occurrence when a legitimate users causes this to happen, and it is unlikely that these numbers seen in the table is caused by system users alone.

An important note is that the increase in occurrences in the first period is caused by duplicates, which happen to be divisible by six minutes. For example, on 2016-02-14 there exists a lot of duplicates playbacks at 01:00:00.000, 04:00:00.000, 01:30:00.000 and 04:30:00.000. Each pair of these timestamps happen to be divisible by six minutes, however, we consider them as being duplicates. In fact, tables in Appendix A show that these occurrences was caused by these duplicates.

Table 18 show that it is statistically possible for users to have online playbacks for this kind of scenario. However, the frequency for its occurrence sky-rocketed in the second suspicious period. Going from normally less than hundred occurrences for normal days, up to fifteen million occurrences when 'Lemonade' was released. Finally, Table 19 show that these affected playbacks was mostly from this album release.

Keep in mind that we have only accounted for the track IDs and not any videos associated with the album. This means that the affected number of playbacks could be higher. In addition, our result in Table 19 accounts for the assumption that first playbacks is legitimate. Which means that they are not counted in these tables.

Date	Total users	Affected users	Affected users %	Total online users	Affected online users	Affected online users %	Total offline users	Affected offline users	Affected offline users %
2016-01-21	174620	1105	0.633	135221	692	0.512	39399	413	1.048
2016-01-22	188796	1214	0.643	149491	778	0.52	39305	436	1.109
2016-01-23	183237	1016	0.554	148330	660	0.445	34907	356	1.02
2016-01-24	171511	910	0.531	137257	572	0.417	34254	338	0.987
2016-01-25	174896	1125	0.643	135543	688	0.508	39353	437	1.11
2016-01-26	180917	1084	0.599	140482	673	0.479	40435	411	1.016
2016-01-27	202757	1280	0.631	165342	893	0.54	37415	387	1.034
2016-01-28	356158	8511	2.39	307284	7489	2.437	48874	1022	2.091
2016-01-29	344910	6690	1.94	277724	4715	1.698	67186	1975	2.94
2016-01-30	324098	5371	1.657	254269	3125	1.229	69829	2246	3.216
2016-01-31	296886	4152	1.399	225798	2311	1.023	71088	1841	2.59
2016-02-01	300715	4826	1.605	222513	2605	1.171	78202	2221	2.84
2016-02-02	300530	4355	1.449	221130	2367	1.07	79400	1988	2.504
2016-02-03	296753	4029	1.358	216748	2188	1.009	80005	1841	2.301
2016-02-04	298583	3835	1.284	217279	2015	0.927	81304	1820	2.239
2016-02-05	312045	3647	1.169	234200	2065	0.882	77845	1582	2.032
2016-02-06	330846	2989	0.903	270729	2054	0.759	60117	935	1.555
2016-02-07	337341	2955	0.876	287555	2286	0.795	49786	669	1.344
2016-02-08	334768	3448	1.03	278546	2595	0.932	56222	853	1.517
2016-02-09	328425	3562	1.085	260760	2379	0.912	67665	1183	1.748
2016-02-10	328089	3362	1.025	257006	2206	0.858	71083	1156	1.626
2016-02-11	355004	3272	0.922	281945	2050	0.727	73059	1222	1.673
2016-02-12	386880	3301	0.853	316405	2179	0.689	70475	1122	1.592
2016-02-13	358217	2885	0.805	291055	1938	0.666	67162	947	1.41
2016-02-14	691041	546777	79.124	609112	485683	79.736	81929	61094	74.569
2016-02-15	747981	660347	88.284	574979	505980	88.0	173002	154367	89.228
2016-02-16	800171	715331	89.397	585803	523973	89.445	214368	191358	89.266
2016-02-17	815881	732172	89.74	574861	516703	89.883	241020	215469	89.399
2016-02-18	806257	719494	89.239	551943	495053	89.693	254314	224441	88.253
2016-02-19	817275	725205	88.735	556034	496245	89.247	261241	228960	87.643
2016-02-20	787117	695868	88.407	532886	475980	89.321	254231	219888	86.491
2016-02-21	732423	638369	87.159	486737	430320	88.409	245686	208049	84.681
2016-02-22	770746	669531	86.868	533728	467605	87.611	237018	201926	85.194
2016-02-23	764584	677408	88.598	529906	476566	89.934	234678	200842	85.582
2016-02-24	760152	12801	1.684	514411	7295	1.418	245741	5506	2.241
2016-02-25	747083	12531	1.677	496204	7087	1.428	250879	5444	2.17
2016-02-26	764275	12554	1.643	512378	7241	1.413	251897	5313	2.109
2016-02-27	741229	10076	1.359	494773	5670	1.146	246456	4406	1.788
2016-02-28	696194	8387	1.205	459151	4713	1.026	237043	3674	1.55
2016-02-29	691263	10413	1.506	449202	5924	1.319	242061	4489	1.854
2016-03-01	696388	10738	1.542	454878	6087	1.338	241510	4651	1.926
2016-03-02	700917	10015	1.429	461109	5608	1.216	239808	4407	1.838
2016-03-03	691915	9716	1.404	451042	5507	1.221	240873	4209	1.747
2016-04-18	461253	6609	1.433	340662	4514	1.325	120591	2095	1.737
2016-04-19	463153	6564	1.417	343033	4463	1.301	120120	2101	1.749
2016-04-20	504825	6214	1.231	402684	4616	1.146	102141	1598	1.565
2016-04-21	494942	5760	1.164	392501	4159	1.06	102441	1601	1.563
2016-04-22	530312	6503	1.226	429837	4917	1.144	100475	1586	1.579
2016-04-23	500494	5382	1.075	398927	3851	0.965	101567	1531	1.507
2016-04-24	1017351	360335	35.419	937338	353206	37.682	80013	7129	8.91
2016-04-25	1084330	474317	43.743	936931	418428	44.659	147399	55889	37.917
2016-04-26	1106615	678624	61.324	921532	576879	62.6	185083	101745	54.973
2016-04-27	1086552	672915	61.931	878715	553454	62.984	207837	119461	57.478
2016-04-28	1066626	694998	65.159	841933	555214	65.945	224693	139784	62.211
2016-04-29	1079856	701579	64.97	854740	556528	65.111	225116	145051	64.434
2016-04-30	1005141	603375	60.029	778704	470196	60.382	226437	133179	58.815
2016-05-01	922822	636170	68.937	703029	481636	68.509	219793	154534	70.309
2016-05-02	923637	624955	67.662	690843	472798	68.438	232794	152157	65.361
2016-05-03	912692	555316	60.844	668396	416447	62.305	244296	138869	56.845
2016-05-04	919118	587380	63.907	683132	446402	65.346	235986	140978	59.74
2016-05-05	889725	581806	65.392	659028	439989	66.763	230697	141817	61.473
2016-05-06	887489	534149	60.187	658611	407554	61.881	228878	126595	55.311
2016-05-07	851475	473762	55.64	628638	367472	58.455	222837	106290	47.699
2016-05-08	790803	266292	33.674	581512	207387	35.663	209291	58905	28.145
2016-05-09	807714	9267	1.147	590649	6183	1.047	217065	3084	1.421

Table 17: Six minutes system users

Date	Total play-backs	Affected play-backs	Affected play-backs %	Total online play-backs	Affected online play-backs	Affected online play-backs %	Total offline play-backs	Affected offline play-backs	Affected offline play-backs %
2016-01-21	5183365	4734	0.091	2887796	35	0.001	2295569	4699	0.205
2016-01-22	5699857	4739	0.083	3197499	32	0.001	2502358	4707	0.188
2016-01-23	5706073	4517	0.079	3320763	56	0.002	2385310	4461	0.187
2016-01-24	4990937	4364	0.087	2877218	38	0.001	2113719	4326	0.205
2016-01-25	5034490	4598	0.091	2775176	48	0.002	2259314	4550	0.201
2016-01-26	5211451	3825	0.073	2861114	32	0.001	2350337	3793	0.161
2016-01-27	5699874	4822	0.085	3115105	43	0.001	2584769	4779	0.185
2016-01-28	10716712	30827	0.288	5406227	81	0.001	5310485	30746	0.579
2016-01-29	10860619	23421	0.216	5522217	56	0.001	5338402	23365	0.438
2016-01-30	10008250	19929	0.199	5200705	77	0.001	4807545	19852	0.413
2016-01-31	8445037	15194	0.18	4380686	29	0.001	4064351	15165	0.373
2016-02-01	8595181	16261	0.189	4260810	55	0.001	4334371	16206	0.374
2016-02-02	8469929	14746	0.174	4153867	35	0.001	4316062	14711	0.341
2016-02-03	8386787	14464	0.172	4130617	51	0.001	4256170	14413	0.339
2016-02-04	8410214	13956	0.166	4128894	30	0.001	4281320	13926	0.325
2016-02-05	9001255	12552	0.139	4503223	34	0.001	4498032	12518	0.278
2016-02-06	8841003	10903	0.123	4623472	34	0.001	4217531	10869	0.258
2016-02-07	8375341	11647	0.139	4562874	51	0.001	3812467	11596	0.304
2016-02-08	8145940	12581	0.154	4244968	44	0.001	3900972	12537	0.321
2016-02-09	8439985	13191	0.156	4289622	44	0.001	4150363	13147	0.317
2016-02-10	8437553	12209	0.145	4261212	56	0.001	4176341	12153	0.291
2016-02-11	8748323	11819	0.135	4431643	34	0.001	4316680	11785	0.273
2016-02-12	9591865	11552	0.12	4932532	55	0.001	4659333	11497	0.247
2016-02-13	9207400	10506	0.114	4815322	32	0.001	4392078	10474	0.238
2016-02-14	52264508	27636779	52.879	25683182	13463259	52.421	26581326	14173520	53.321
2016-02-15	62315131	36180835	58.061	28423017	16350436	57.525	33892114	19830399	58.51
2016-02-16	62575347	36524250	58.368	27216556	15733229	57.808	35358791	20791021	58.8
2016-02-17	61635277	36208840	58.747	26096222	15176282	58.155	35539055	21032558	59.182
2016-02-18	58176702	34180560	58.753	24279133	14144850	58.259	33897569	20035710	59.107
2016-02-19	57453384	33753034	58.749	23863079	13890396	58.209	33590305	19862638	59.132
2016-02-20	51238240	30170202	58.882	21695419	12661642	58.361	29542821	17508560	59.265
2016-02-21	44012913	25889125	58.822	19017377	11110721	58.424	24995536	14778404	59.124
2016-02-22	48123726	28256470	58.716	20139829	11716634	58.176	27983897	16539836	59.105
2016-02-23	47818784	28293894	59.169	19908725	11683244	58.684	27910059	16610650	59.515
2016-02-24	19205376	42563	0.222	8020004	62	0.001	11185372	42501	0.38
2016-02-25	19155488	40865	0.213	7933048	54	0.001	11222440	40811	0.364
2016-02-26	19895000	41891	0.211	8316062	62	0.001	11578938	41829	0.361
2016-02-27	18410754	33903	0.184	7817765	89	0.001	10592989	33814	0.319
2016-02-28	16341019	27971	0.171	7006815	61	0.001	9334204	27910	0.299
2016-02-29	17041782	34080	0.2	7049968	91	0.001	9991814	33989	0.34
2016-03-01	17519578	34691	0.198	7264171	72	0.001	10255407	34619	0.338
2016-03-02	17260480	33085	0.192	7182545	62	0.001	10077935	33023	0.328
2016-03-03	17326476	32095	0.185	7175051	112	0.002	10151425	31983	0.315
2016-04-18	13094984	24745	0.189	5480281	43	0.001	7614703	24702	0.324
2016-04-19	13228953	26010	0.197	5561693	91	0.002	7667260	25919	0.338
2016-04-20	13716969	23802	0.174	5943181	72	0.001	7773788	23730	0.305
2016-04-21	13592572	21256	0.156	6080560	37	0.001	7512012	21219	0.282
2016-04-22	15716545	23431	0.149	7204431	65	0.001	8512114	23366	0.275
2016-04-23	14539943	20743	0.143	6686559	116	0.002	7853384	20627	0.263
2016-04-24	32844244	8889139	27.065	16533941	4154960	25.13	16310303	4734179	29.026
2016-04-25	61648530	37252611	60.427	27532332	15483150	56.236	34116198	21769461	63.81
2016-04-26	51762664	30028854	58.013	23271706	12924148	55.536	28490958	17104706	60.036
2016-04-27	51443095	30894233	60.055	22441805	12790979	56.996	29001290	18103254	62.422
2016-04-28	49571047	30584075	61.697	21060520	12196311	57.911	28510527	18387764	64.495
2016-04-29	45740028	28088101	61.408	19304866	11067972	57.333	26435162	17020129	64.384
2016-04-30	44747668	28206684	63.035	18482843	10821694	58.55	26264825	17384990	66.191
2016-05-01	38826732	26924745	69.346	16407601	10690627	65.157	22419131	16234118	72.412
2016-05-02	36971583	24016084	64.958	15561500	9739413	62.587	21410083	14276671	66.682
2016-05-03	34043783	19841920	58.284	14283511	7939668	55.586	19760272	11902252	60.233
2016-05-04	32862327	18701918	56.91	14013298	7602803	54.254	18849029	11099115	58.884
2016-05-05	31535242	17950753	56.923	13427299	7319756	54.514	18107943	10630997	58.709
2016-05-06	30227071	15728090	52.033	12798897	6397223	49.983	17428174	9330867	53.539
2016-05-07	26738540	13342584	49.9	11477044	5760631	50.193	15261496	7581953	49.68
2016-05-08	20337761	5342108	26.267	8893020	2327690	26.174	11444741	3014418	26.339
2016-05-09	19254690	33567	0.174	8408779	96	0.001	10845911	33471	0.309

Date	Online users online play-backs	Online users offline play-backs	Offline users online play-backs	Offline users offline play-backs	Affected play-backs from albums	Affected play-backs from albums %	Affected online play-backs from albums	Affected offline play-backs from albums
2016-01-21	35	2856	0	1843	0	0.0	0.0	0
2016-01-22	32	2871	0	1836	0	0.0	0.0	0
2016-01-23	56	2855	0	1606	0	0.0	0.0	0
2016-01-24	38	2676	0	1650	0	0.0	0.0	0
2016-01-25	48	2736	0	1814	0	0.0	0.0	0
2016-01-26	32	2298	0	1495	0	0.0	0.0	0
2016-01-27	43	3215	0	1564	0	0.0	0.0	0
2016-01-28	81	26818	0	3928	0	0.0	0.0	0
2016-01-29	56	15804	0	7561	0	0.0	0.0	0
2016-01-30	77	11464	0	8388	0	0.0	0.0	0
2016-01-31	29	8286	0	6879	0	0.0	0.0	0
2016-02-01	55	8655	0	7551	0	0.0	0.0	0
2016-02-02	35	7712	0	6999	0	0.0	0.0	0
2016-02-03	51	7445	0	6968	0	0.0	0.0	0
2016-02-04	30	6883	0	7043	0	0.0	0.0	0
2016-02-05	34	6974	0	5544	0	0.0	0.0	0
2016-02-06	34	6898	0	3971	0	0.0	0.0	0
2016-02-07	51	8666	0	2930	0	0.0	0.0	0
2016-02-08	44	9162	0	3375	0	0.0	0.0	0
2016-02-09	44	8524	0	4623	0	0.0	0.0	0
2016-02-10	56	7796	0	4357	0	0.0	0.0	0
2016-02-11	34	6871	0	4914	0	0.0	0.0	0
2016-02-12	55	6649	0	4848	0	0.0	0.0	0
2016-02-13	32	6393	0	4081	0	0.0	0.0	0
2016-02-14	13463259	11832874	0	2340646	18223353	65.939	8536670	9686683
2016-02-15	16350436	12954065	0	6876334	23135700	63.945	9614250	13521450
2016-02-16	15733229	12949491	0	7841530	21667799	59.324	8172642	13495157
2016-02-17	15176282	12590919	0	8441639	19833846	54.776	7003216	12830630
2016-02-18	14144850	11802194	0	8233516	17197908	50.315	5811364	11386544
2016-02-19	13890396	11730727	0	8131911	15643115	46.346	5099225	10543890
2016-02-20	12661642	10457810	0	7050750	12480282	41.366	3879253	8601029
2016-02-21	11110721	8642778	0	6135626	9962709	38.482	3145303	6817406
2016-02-22	11716634	10130726	0	6409110	11141095	39.428	3519729	7621366
2016-02-23	11683244	10310383	0	6300267	10243031	36.202	3118388	7124643
2016-02-24	62	23929	0	18572	25803	60.623	27	25776
2016-02-25	54	22979	0	17832	23822	58.294	14	23808
2016-02-26	62	24186	0	17643	24160	57.673	21	24139
2016-02-27	89	18638	0	15176	17695	52.193	10	17685
2016-02-28	61	15543	0	12367	14004	50.066	11	13993
2016-02-29	91	18647	0	15342	18184	53.357	14	18170
2016-03-01	72	19309	0	15310	17619	50.788	10	17609
2016-03-02	62	17935	0	15088	16246	49.104	8	16238
2016-03-03	112	18021	0	13962	15422	48.051	13	15409
2016-04-18	43	16786	0	7916	0	0.0		
2016-04-19	91	16645	0	9274	0	0.0		
2016-04-20	72	17134	0	6596	0	0.0		
2016-04-21	37	14971	0	6248	0	0.0		
2016-04-22	65	17188	0	6178	0	0.0		
2016-04-23	116	14082	0	6545	0	0.0		
2016-04-24	4154960	4586056	0	148123	4491857	50.532		
2016-04-25	15483150	17683516	0	4085945	31019685	83.268		
2016-04-26	12924148	13004545	0	4100161	17057282	56.803		
2016-04-27	12790979	12993169	0	5110085	18279983	59.17		
2016-04-28	12196311	12815458	0	5572306	17106522	55.933		
2016-04-29	11067972	11818926	0	5201203	14688085	52.293		
2016-04-30	10821694	11659064	0	5725926	17427384	61.785		
2016-05-01	10690627	10691857	0	5542261	13780163	51.18		
2016-05-02	9739413	9335636	0	4941035	10853979	45.195		
2016-05-03	7939668	7597812	0	4304440	7735233	38.984		
2016-05-04	7602803	7181958	0	3917157	6226843	33.295		
2016-05-05	7319756	6956214	0	3674783	5080394	28.302		
2016-05-06	6397223	6249872	0	3080995	3491402	22.199		
2016-05-07	5760631	5261225	0	2320728	1480767	11.098		
2016-05-08	2327690	2065418	0	949000	671018	12.561		
2016-05-09	96	21549	0	11922	10869	32.38		

Table 19: Six minutes affected users playbacks

5.10 Summary of findings

This subsection summarises our findings for each suspicious period. Tables 20 and 21 summarises the suspicious days in each period, respectively. While Table 22 summarises all suspicious days from the two periods. We can see that 93.79% of users was affected by at least one of the impossible scenarios, while 83.985% of all users was affected in the second suspicious period. It was in total 90.828% of users affected of these impossible scenarios in these two periods.

Tables 23 and 24 summarises how many playbacks was affected by each impossible scenario. Almost 319 000 000 playbacks was affected during the ten suspicious days in the first period, that is 58.454% of all playbacks occurring during the same period. From these affected playbacks, there are almost 159 000 000 playbacks who have played tracks found in ‘Life of Pablo’. Which means that half (49.851%) of all affected playbacks had played tracks from this album.

Table 24 show that 57.683% of all playbacks was affected with at least one impossible scenario. While 67.928% of those affected playbacks had track IDs from the ‘Lemonade’ album. Note that tables in Subsection 5.9 accounts for the first playback as being legitimate, however, tables in this section does not take this into account. Which means that numbers in Tables 24 and 25 contains the first legitimate playback divisible by six minutes.

Type	Total users	Affected users	Affected users %	Total online users	Affected online users	Affected online users %	Total offline users	Affected offline users	Affected offline users %
Two duplicates	1461669	1158967	79.291	1405818	1060506	75.437	715305	467000	65.287
Three or more duplicates	1461669	908178	62.133	1405818	813622	57.875	715305	323737	45.259
Two unequal duplicates	1461669	296867	20.31	1405818	186840	13.29	715305	123268	17.233
Three or more unequal duplicates	1461669	1332871	91.188	1405818	1244367	88.516	715305	619381	86.59
All	1461669	1370899	93.79	1405818	1285582	91.447	715305	647518	90.523

Table 20: Affected users 2016-02-14 - 2016-02-23

Type	Total users	Affected users	Affected users %	Total online users	Affected online users	Affected online users %	Total offline users	Affected offline users	Affected offline users %
Two duplicates	2086838	498917	23.908	2032841	408721	20.106	956754	153834	16.079
Three or more duplicates	2086838	116652	5.59	2032841	94961	4.671	956754	30492	3.187
Two unequal duplicates	2086838	55346	2.652	2032841	42250	2.078	956754	15449	1.615
Three or more unequal duplicates	2086838	10201	0.489	2032841	8614	0.424	956754	5054	0.528
Six minutes	2086838	1737008	83.236	2032841	1660464	81.682	956754	703241	73.503
All	2086838	1752636	83.985	2032841	1676305	82.461	956754	721858	75.449

Table 21: Affected users 2016-04-24 - 2016-05-08

Type	Total users	Affected users	Affected users %	Total online users	Affected online users	Affected online users %	Total offline users	Affected offline users	Affected offline users %
Two duplicates	2915953	1508749	51.741	2858752	1353014	47.329	1450699	592913	40.871
Three or more duplicates	2915953	989679	33.94	2858752	881620	30.839	1450699	349314	24.079
Two unequal duplicates	2915953	346419	11.88	2858752	225863	7.901	1450699	137918	9.507
Three or more unequal duplicates	2915953	1336364	45.829	2858752	1247680	43.644	1450699	622007	42.876
Six minutes	2915953	2638764	90.494	2858752	2533264	88.614	1450699	1233476	85.026
All	2915953	2648493	90.828	2858752	2544783	89.017	1450699	1248529	86.064

Table 22: Affected users 2016-02-14 - 2016-02-23 and 2016-04-24 - 2016-05-08

Type	Total playbacks	Affected playbacks	Affected playbacks %	Affected playbacks from albums	Affected playbacks from albums %
Two duplicates	545614012	64618580	11.843	36830106	56.996
Three or more duplicates	545614012	102776725	18.837	74166485	72.163
Two unequal duplicates	545614012	1374574	0.252	644663	46.899
Three or more unequal duplicates	545614012	314173882	57.582	156992700	49.97
All	545614012	318934712	58.454	158991922	49.851

Table 23: Affected playbacks 2016-02-14 - 2016-02-23

Type	Total playbacks	Affected playbacks	Affected playbacks %	Affected playbacks from albums	Affected playbacks from albums %
Two duplicates	589300315	7212646	1.224	4299384	59.609
Three or more duplicates	589300315	2531457	0.43	1093581	43.2
Two unequal duplicates	589300315	186960	0.032	136157	72.827
Three or more unequal duplicates	589300315	1176825	0.2	285073	24.224
Six minutes	589300315	335791899	56.981	169390597	50.445
All	589300315	339927886	57.683	230906389	67.928

Table 24: Affected playbacks 2016-04-24 - 2016-05-08

Type	Total playbacks	Affected playbacks	Affected playbacks %	Affected playbacks from albums	Affected playbacks from albums %
Two duplicates	1134914327	71831226	6.329	41129490	57.259
Three or more duplicates	1134914327	105308182	9.279	75260066	71.466
Two unequal duplicates	1134914327	1561534	0.138	780820	50.003
Three or more unequal duplicates	1134914327	315350707	27.786	157277773	49.874
Six minutes	1134914327	652885888	57.527	328919435	50.379
All	1134914327	658862598	58.054	389898311	59.177

Table 25: Affected playbacks 2016-02-14 - 2016-02-23 and 2016-04-24 - 2016-05-08

6 Conclusion

We were approached by DN to investigate possible fraudulent manipulation of data in the database of a music streaming service. We have through advanced statistical analysis determined that there has in fact been a manipulation of the data at particular times. The manipulation appears targeted towards a very specific set of track IDs, related to two distinct albums.

It is difficult to determine the exact cause and means of the manipulation, but it is likely that several methods were used. The manipulation looks to have become more sophisticated during the period for which we have data. It starts with simple duplication and possible insertion of fabricated playbacks of tracks, to more advanced (and difficult to detect) manipulation at the timestamp by adjusting the timestamps of duplicates with something evenly divisible by six minutes. The advanced manipulation was more difficult to detect, because playbacks have not been simply duplicated or inserted into the log files. Our analysis also show that a considerable amount of system users was affected by the manipulation during these days.

It is very unlikely (but not impossible) the manipulation is the result of an external attack or that an outside source has affected the accuracy of the data. The absence of noise in the data and log files suggests that a Structured Query Language (SQL) based attack was not the cause of the manipulation. Also, unrelated third-party attackers do not have motivation for manipulating the playbacks for very specific tracks. Our analysis also shows a significant number of system users were affected by the manipulation, which may exclude a external or user originated manipulation. As such the manipulation likely originates from within the streaming service itself. Due to the targeted nature and extent of the manipulation, it is very unlikely that this manipulation was solely the result of a code based bug or other anomalies.

Statement of conflicts

The writers of this report confirm that we have no conflict of interest of any kind, other than any which are set out below. The writers will advise Dagens Næringsliv, if between the date of this report and any further request if there is any change in circumstances which affects this statement.

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A Additional modulo six summaries

We mentioned that a lot of the entries was caused by identical duplicates with timestamps at 01:00:00, 01:30:00, 04:00:00 and 04:30:00. To demonstrate this, we have removed these duplicates in the tables below. Keep in mind that we have removed all occurrences of these timestamps for each day. This show that most of the affected playbacks and users in the first period was duplicates, rather than having timestamps which are divisible by six minutes.

Date	Total users	Affected users	Percentage	Total online users	Affected online users	Online percentage	Total offline users	Affected offline users	Offline percentage
2016-01-21	174620	1105	0.633	135221	692	0.512	39399	413	1.048
2016-01-22	188796	1214	0.643	149491	778	0.52	39305	436	1.109
2016-01-23	183237	1016	0.554	148330	660	0.445	34907	356	1.02
2016-01-24	171511	910	0.531	137257	572	0.417	34254	338	0.987
2016-01-25	174896	1125	0.643	135543	688	0.508	39353	437	1.11
2016-01-26	180917	1084	0.599	140482	673	0.479	40435	411	1.016
2016-01-27	202757	1280	0.631	165342	893	0.54	37415	387	1.034
2016-01-28	356158	8511	2.39	307284	7489	2.437	48874	1022	2.091
2016-01-29	344910	6690	1.94	277724	4715	1.698	67186	1975	2.94
2016-01-30	324098	5371	1.657	254269	3125	1.229	69829	2246	3.216
2016-01-31	296886	4152	1.399	225798	2151	1.023	71088	1841	2.59
2016-02-01	300715	4826	1.605	222513	2605	1.171	78202	2221	2.84
2016-02-02	300530	4355	1.449	221130	2367	1.07	79400	1988	2.504
2016-02-03	296753	4029	1.358	216748	2188	1.009	80005	1841	2.301
2016-02-04	298583	3835	1.284	217279	2015	0.927	81304	1820	2.239
2016-02-05	312045	3647	1.169	234200	2065	0.882	77845	1582	2.032
2016-02-06	330846	2989	0.903	270729	2054	0.759	60117	935	1.555
2016-02-07	337341	2955	0.876	287555	2286	0.795	49786	669	1.344
2016-02-08	334768	3448	1.03	278546	2595	0.932	56222	853	1.517
2016-02-09	328425	3562	1.085	260760	2379	0.912	67665	1183	1.748
2016-02-10	328089	3362	1.025	257006	2206	0.858	71083	1156	1.626
2016-02-11	355004	3272	0.922	281945	2050	0.727	73059	1222	1.673
2016-02-12	386880	3301	0.853	316405	2179	0.689	70475	1122	1.592
2016-02-13	358217	2885	0.805	291055	1938	0.666	67162	947	1.41
2016-02-14	691041	39410	5.703	609112	33426	5.488	81929	5984	7.304
2016-02-15	747981	50170	6.707	574979	31501	5.479	173002	18669	10.791
2016-02-16	800171	52160	6.519	585803	31050	5.3	214368	21110	9.848
2016-02-17	815881	50153	6.147	574861	28500	4.958	241020	21653	8.984
2016-02-18	806257	45902	5.693	551943	25548	4.629	254314	20354	8.003
2016-02-19	817275	44186	5.407	556034	24447	4.397	261241	19739	7.556
2016-02-20	787117	36293	4.611	532886	20427	3.833	254231	15866	6.241
2016-02-21	732423	638369	87.159	486737	430320	88.409	245686	208049	84.681
2016-02-22	770746	669531	86.868	533728	467605	87.611	237018	201926	85.194
2016-02-23	764584	677408	88.598	529906	476566	89.934	234678	200842	85.582
2016-02-24	760152	12801	1.684	514411	7295	1.418	245741	5506	2.241
2016-02-25	747083	12531	1.677	496204	7087	1.428	250879	5444	2.17
2016-02-26	764275	12554	1.643	512378	7241	1.413	251897	5313	2.109
2016-02-27	741229	10076	1.359	494773	5670	1.146	246456	4406	1.788
2016-02-28	696194	8387	1.205	459151	4713	1.026	237043	3674	1.55
2016-02-29	691263	10413	1.506	449202	5924	1.319	242061	4489	1.854
2016-03-01	696388	10738	1.542	454878	6087	1.338	241510	4651	1.926
2016-03-02	700917	10015	1.429	461109	5608	1.216	239808	4407	1.838
2016-03-03	691915	9716	1.404	451042	5507	1.221	240873	4209	1.747
2016-04-18	461253	6609	1.433	340662	4514	1.325	120591	2095	1.737
2016-04-19	463153	6564	1.417	343033	4463	1.301	120120	2101	1.749
2016-04-20	504825	6214	1.231	402684	4616	1.146	102141	1598	1.565
2016-04-21	494942	5760	1.164	392501	4159	1.06	102441	1601	1.563
2016-04-22	530312	6503	1.226	429837	4917	1.144	100475	1586	1.579
2016-04-23	500494	5382	1.075	398927	3851	0.965	101567	1531	1.507
2016-04-24	1017351	360335	35.419	937338	353206	37.682	80013	7129	8.91
2016-04-25	1084330	474317	43.743	936931	418428	44.659	147399	55889	37.917
2016-04-26	1106615	678624	61.324	921532	576879	62.6	185083	101745	54.973
2016-04-27	1086552	672915	61.931	878715	553454	62.984	207837	119461	57.478
2016-04-28	1066626	694998	65.159	841933	555214	65.945	224693	139784	62.211
2016-04-29	1079856	701579	64.97	854740	556528	65.111	225116	145051	64.434
2016-04-30	1005141	603375	60.029	778704	470196	60.382	226437	133179	58.815
2016-05-01	922822	636170	68.937	703029	481636	68.509	219793	154534	70.309
2016-05-02	923637	624955	67.662	690843	472798	68.438	232794	152157	65.361
2016-05-03	912692	555316	60.844	668396	416447	62.305	244296	138869	56.845
2016-05-04	919118	587380	63.907	683132	446402	65.346	235986	140978	59.74
2016-05-05	889725	581806	65.392	659028	439989	66.763	230697	141817	61.473
2016-05-06	887489	534149	60.187	658611	407554	61.881	228878	126595	55.311
2016-05-07	851475	473762	55.64	628638	367472	58.455	222837	106290	47.699
2016-05-08	790803	266292	33.674	581512	207387	35.663	209291	58905	28.145
2016-05-09	807714	9267	1.147	590649	6183	1.047	217065	3084	1.421

Table 26: Six minutes system users minus 01:00:00 and 04:00:00

Date	Total play-backs	Affected play-backs	Affected play-backs %	Total online play-backs	Affected online play-backs	Affected online play-backs %	Total offline play-backs	Affected offline play-backs	Affected offline play-backs %
2016-01-21	5183365	4733	0.091	2887796	35	0.001	2295569	4698	0.205
2016-01-22	5699857	4738	0.083	3197499	32	0.001	2502358	4706	0.188
2016-01-23	5706073	4517	0.079	3320763	56	0.002	2385310	4461	0.187
2016-01-24	4990937	4364	0.087	2877218	38	0.001	2113719	4326	0.205
2016-01-25	5034490	4598	0.091	2775176	48	0.002	2259314	4550	0.201
2016-01-26	5211451	3825	0.073	2861114	32	0.001	2350337	3793	0.161
2016-01-27	5699874	4822	0.085	3115105	43	0.001	2584769	4779	0.185
2016-01-28	10716712	30827	0.288	5406227	81	0.001	5310485	30746	0.579
2016-01-29	10860619	23421	0.216	5522217	56	0.001	5338402	23365	0.438
2016-01-30	10008250	19929	0.199	5200705	77	0.001	4807545	19852	0.413
2016-01-31	8445037	15193	0.18	4380686	29	0.001	4064351	15164	0.373
2016-02-01	8595181	16261	0.189	4260810	55	0.001	4334371	16206	0.374
2016-02-02	8469929	14745	0.174	4153867	35	0.001	4316062	14710	0.341
2016-02-03	8386787	14463	0.172	4130617	51	0.001	4256170	14412	0.339
2016-02-04	8410214	13956	0.166	4128894	30	0.001	4281320	13926	0.325
2016-02-05	9001255	12552	0.139	4503223	34	0.001	4498032	12518	0.278
2016-02-06	8841003	10903	0.123	4623472	34	0.001	4217531	10869	0.258
2016-02-07	8375341	11647	0.139	4562874	51	0.001	3812467	11596	0.304
2016-02-08	8145940	12579	0.154	4244968	44	0.001	3900972	12535	0.321
2016-02-09	8439985	13191	0.156	4289622	44	0.001	4150363	13147	0.317
2016-02-10	8437553	12209	0.145	4261212	56	0.001	4176341	12153	0.291
2016-02-11	8748323	11819	0.135	4431643	34	0.001	4316680	11785	0.273
2016-02-12	9591865	11552	0.12	4932532	55	0.001	4659333	11497	0.247
2016-02-13	9207400	10506	0.114	4815322	32	0.001	4392078	10474	0.238
2016-02-14	52264508	155408	0.297	25683182	161	0.001	26581326	155247	0.584
2016-02-15	62315131	187957	0.302	28423017	190	0.001	33892114	187767	0.554
2016-02-16	62575347	192229	0.307	27216556	160	0.001	35358791	192069	0.543
2016-02-17	61635277	183607	0.298	26096222	134	0.001	35539055	183473	0.516
2016-02-18	58176702	167039	0.287	24279133	90	0.0	33897569	166949	0.493
2016-02-19	57453384	167045	0.291	23863079	100	0.0	33590305	166945	0.497
2016-02-20	51238240	140053	0.273	21695419	74	0.0	29542821	139979	0.474
2016-02-21	44012913	25888897	58.821	19017377	11110721	58.424	24995536	14778176	59.123
2016-02-22	48123726	28256300	58.716	20139829	11716634	58.176	27983897	16539666	59.104
2016-02-23	47818784	28293730	59.169	19908725	11683244	58.684	27910059	16610486	59.514
2016-02-24	19205376	42561	0.222	8020004	62	0.001	11185372	42499	0.38
2016-02-25	19155488	40864	0.213	7933048	54	0.001	11222440	40810	0.364
2016-02-26	19895000	41890	0.211	8316062	62	0.001	11578938	41828	0.361
2016-02-27	18410754	33902	0.184	7817765	89	0.001	10592989	33813	0.319
2016-02-28	16341019	27970	0.171	7006815	61	0.001	9334204	27909	0.299
2016-02-29	17041782	34077	0.2	7049968	91	0.001	9991814	33986	0.34
2016-03-01	17519578	34691	0.198	7264171	72	0.001	10255407	34619	0.338
2016-03-02	17260480	33083	0.192	7182545	62	0.001	10077935	33021	0.328
2016-03-03	17326476	32095	0.185	7175051	112	0.002	10151425	31983	0.315
2016-04-18	13094984	24745	0.189	5480281	43	0.001	7614703	24702	0.324
2016-04-19	13228953	26008	0.197	5561693	91	0.002	7667260	25917	0.338
2016-04-20	13716969	23802	0.174	5943181	72	0.001	7773788	23730	0.305
2016-04-21	13592572	21254	0.156	6080560	37	0.001	7512012	21217	0.282
2016-04-22	15716545	23430	0.149	7204431	65	0.001	8512114	23365	0.274
2016-04-23	14539943	20742	0.143	6686559	116	0.002	7853384	20626	0.263
2016-04-24	32844244	8889054	27.064	16533941	4154960	25.13	16310303	4734094	29.025
2016-04-25	61648530	37250072	60.423	27532332	15483150	56.236	34116198	21766922	63.802
2016-04-26	51762664	30028275	58.011	23271706	12924148	55.536	28490958	17104127	60.034
2016-04-27	51443095	30893766	60.054	22441805	12790979	56.996	29001290	18102787	62.421
2016-04-28	49571047	30583689	61.697	21060520	12196310	57.911	28510527	18387379	64.493
2016-04-29	45740028	28087747	61.407	19304866	11067972	57.333	26435162	17019775	64.383
2016-04-30	44747668	28206298	63.034	18482843	10821693	58.55	26264825	17384605	66.19
2016-05-01	38826732	26924441	69.345	16407601	10690626	65.157	22419131	16233815	72.411
2016-05-02	36971583	24015794	64.957	15561500	9739413	62.587	21410083	14276381	66.681
2016-05-03	34043783	19841687	58.283	14283511	7939668	55.586	19760272	11902019	60.232
2016-05-04	32862327	18701656	56.909	14013298	7602803	54.254	18849029	11098853	58.883
2016-05-05	31535242	17950517	56.922	13427299	7319756	54.514	18107943	10630761	58.708
2016-05-06	30227071	15727877	52.032	12798897	6397223	49.983	17428174	9330654	53.538
2016-05-07	26738540	13342339	49.899	11477044	5760631	50.193	15261496	7581708	49.679
2016-05-08	20337761	5341960	26.266	8893020	2327690	26.174	11444741	3014270	26.338
2016-05-09	19254690	33567	0.174	8408779	96	0.001	10845911	33471	0.309

Date	Online users online play-backs	Online users offline play-backs	Offline users online play-backs	Offline users offline play-backs	Affected play-backs from albums	Affected play-backs from albums %	Affected online play-backs from albums	Affected offline play-backs from albums
2016-01-21	35	2855	0	1843	0	0.0	0	0
2016-01-22	32	2870	0	1836	0	0.0	0	0
2016-01-23	56	2855	0	1606	0	0.0	0	0
2016-01-24	38	2676	0	1650	0	0.0	0	0
2016-01-25	48	2736	0	1814	0	0.0	0	0
2016-01-26	32	2298	0	1495	0	0.0	0	0
2016-01-27	43	3215	0	1564	0	0.0	0	0
2016-01-28	81	26818	0	3928	0	0.0	0	0
2016-01-29	56	15804	0	7561	0	0.0	0	0
2016-01-30	77	11464	0	8388	0	0.0	0	0
2016-01-31	29	8285	0	6879	0	0.0	0	0
2016-02-01	55	8655	0	7551	0	0.0	0	0
2016-02-02	35	7712	0	6998	0	0.0	0	0
2016-02-03	51	7445	0	6967	0	0.0	0	0
2016-02-04	30	6883	0	7043	0	0.0	0	0
2016-02-05	34	6974	0	5544	0	0.0	0	0
2016-02-06	34	6898	0	3971	0	0.0	0	0
2016-02-07	51	8666	0	2930	0	0.0	0	0
2016-02-08	44	9161	0	3374	0	0.0	0	0
2016-02-09	44	8524	0	4623	0	0.0	0	0
2016-02-10	56	7796	0	4357	0	0.0	0	0
2016-02-11	34	6871	0	4914	0	0.0	0	0
2016-02-12	55	6649	0	4848	0	0.0	0	0
2016-02-13	32	6393	0	4081	0	0.0	0	0
2016-02-14	161	120820	0	34427	88865	57.182	108	88757
2016-02-15	190	116188	0	71579	121167	64.465	130	121037
2016-02-16	160	113268	0	78801	120144	62.5	97	120047
2016-02-17	134	106524	0	76949	106938	58.243	67	106871
2016-02-18	90	96285	0	70664	90549	54.208	50	90499
2016-02-19	100	95785	0	71160	81565	48.828	39	81526
2016-02-20	74	83146	0	56833	58383	41.686	22	58361
2016-02-21	11110721	8642658	0	6135518	9962557	38.482	3145303	6817254
2016-02-22	11716634	10130640	0	6409026	11141005	39.428	3519729	7621276
2016-02-23	11683244	10310289	0	6300197	10242937	36.202	3118388	7124549
2016-02-24	62	23928	0	18571	25803	60.626	27	25776
2016-02-25	54	22979	0	17831	23821	58.293	14	23807
2016-02-26	62	24185	0	17643	24160	57.675	21	24139
2016-02-27	89	18637	0	15176	17695	52.195	10	17685
2016-02-28	61	15543	0	12366	14003	50.064	11	13992
2016-02-29	91	18646	0	15340	18182	53.356	14	18168
2016-03-01	72	19309	0	15310	17619	50.788	10	17609
2016-03-02	62	17933	0	15088	16245	49.104	8	16237
2016-03-03	112	18021	0	13962	15422	48.051	13	15409
2016-04-18	43	16786	0	7916	0	0.0		
2016-04-19	91	16643	0	9274	0	0.0		
2016-04-20	72	17134	0	6596	0	0.0		
2016-04-21	37	14969	0	6248	0	0.0		
2016-04-22	65	17188	0	6177	0	0.0		
2016-04-23	116	14081	0	6545	0	0.0		
2016-04-24	4154960	4585973	0	148121	4491773	50.532		
2016-04-25	15483150	17681328	0	4085594	31017146	83.267		
2016-04-26	12924148	13004107	0	4100020	17056863	56.803		
2016-04-27	12790979	12992832	0	5109955	18279699	59.17		
2016-04-28	12196310	12815192	0	5572187	17106277	55.933		
2016-04-29	11067972	11818682	0	5201093	14687884	52.293		
2016-04-30	10821693	11658808	0	5725797	17427147	61.785		
2016-05-01	10690626	10691652	0	5542163	13780019	51.18		
2016-05-02	9739413	9335450	0	4940931	10853816	45.194		
2016-05-03	7939668	7597657	0	4304362	7735129	38.984		
2016-05-04	7602803	7181812	0	3917041	6226731	33.295		
2016-05-05	7319756	6956058	0	3674703	5080300	28.302		
2016-05-06	6397223	6249728	0	3080926	3491320	22.198		
2016-05-07	5760631	5261052	0	2320656	1480685	11.098		
2016-05-08	2327690	2065316	0	948954	670964	12.56		
2016-05-09	96	21549	0	11922	5668	16.886		

A ADDITIONAL MODULO SIX SUMMARIES

Table 28: Six minutes affected users playbacks minus 01:00:00 and 04:00:00

Date	Total users	Affected users	Percentage	Total online users	Affected online users	Online percentage	Total offline users	Affected offline users	Offline percentage
2016-01-21	174620	1105	0.633	135221	692	0.512	39399	413	1.048
2016-01-22	188796	1214	0.643	149491	778	0.52	39305	436	1.109
2016-01-23	183237	1016	0.554	148330	660	0.445	34907	356	1.02
2016-01-24	171511	910	0.531	137257	572	0.417	34254	338	0.987
2016-01-25	174896	1125	0.643	135543	688	0.508	39353	437	1.11
2016-01-26	180917	1084	0.599	140482	673	0.479	40435	411	1.016
2016-01-27	202757	1280	0.631	165342	893	0.54	37415	387	1.034
2016-01-28	356158	8511	2.39	307284	7489	2.437	48874	1022	2.091
2016-01-29	344910	6690	1.94	277724	4715	1.698	67186	1975	2.94
2016-01-30	324098	5371	1.657	254269	3125	1.229	69829	2246	3.216
2016-01-31	296886	4152	1.399	225798	2311	1.023	71088	1841	2.59
2016-02-01	300715	4826	1.605	222513	2605	1.171	78202	2221	2.84
2016-02-02	300530	4355	1.449	221130	2367	1.07	79400	1988	2.504
2016-02-03	296753	4029	1.358	216748	2188	1.009	80005	1841	2.301
2016-02-04	298583	3835	1.284	217279	2015	0.927	81304	1820	2.239
2016-02-05	312045	3647	1.169	234200	2065	0.882	77845	1582	2.032
2016-02-06	330846	2989	0.903	270729	2054	0.759	60117	935	1.555
2016-02-07	337341	2955	0.876	287555	2286	0.795	49786	669	1.344
2016-02-08	334768	3448	1.03	278546	2595	0.932	56222	853	1.517
2016-02-09	328425	3562	1.085	260760	2379	0.912	67665	1183	1.748
2016-02-10	328089	3362	1.025	257006	2206	0.858	71083	1156	1.626
2016-02-11	355004	3272	0.922	281945	2050	0.727	73059	1222	1.673
2016-02-12	386880	3301	0.853	316405	2179	0.689	70475	1122	1.592
2016-02-13	358217	2885	0.805	291055	1938	0.666	67162	947	1.41
2016-02-14	691041	39372	5.697	609112	33397	5.483	81929	5975	7.293
2016-02-15	747981	50003	6.685	574979	31417	5.464	173002	18586	10.743
2016-02-16	800171	52003	6.499	585803	30962	5.285	214368	21041	9.815
2016-02-17	815881	49971	6.125	574861	28403	4.941	241020	21568	8.949
2016-02-18	806257	45711	5.67	551943	25453	4.612	254314	20258	7.966
2016-02-19	817275	43998	5.384	556034	24342	4.378	261241	19656	7.524
2016-02-20	787117	36090	4.585	532886	20328	3.815	254231	15762	6.2
2016-02-21	732423	29596	4.041	486737	16103	3.308	245686	13493	5.492
2016-02-22	770746	34207	4.438	533728	19928	3.734	237018	14279	6.024
2016-02-23	764584	33359	4.363	529906	19746	3.726	234678	13613	5.801
2016-02-24	760152	12801	1.684	514411	7295	1.418	245741	5506	2.241
2016-02-25	747083	12531	1.677	496204	7087	1.428	250879	5444	2.17
2016-02-26	764275	12554	1.643	512378	7241	1.413	251897	5313	2.109
2016-02-27	741229	10076	1.359	494773	5670	1.146	246456	4406	1.788
2016-02-28	696194	8387	1.205	459151	4713	1.026	237043	3674	1.55
2016-02-29	691263	10413	1.506	449202	5924	1.319	242061	4489	1.854
2016-03-01	696388	10738	1.542	454878	6087	1.338	241510	4651	1.926
2016-03-02	700917	10015	1.429	461109	5608	1.216	239808	4407	1.838
2016-03-03	691915	9716	1.404	451042	5507	1.221	240873	4209	1.747
2016-04-18	461253	6609	1.433	340662	4514	1.325	120591	2095	1.737
2016-04-19	463153	6564	1.417	343033	4463	1.301	120120	2101	1.749
2016-04-20	504825	6214	1.231	402684	4616	1.146	102141	1598	1.565
2016-04-21	494942	5760	1.164	392501	4159	1.06	102441	1601	1.563
2016-04-22	530312	6503	1.226	429837	4917	1.144	100475	1586	1.579
2016-04-23	500494	5382	1.075	398927	3851	0.965	101567	1531	1.507
2016-04-24	1017351	360335	35.419	937338	353206	37.682	80013	7129	8.91
2016-04-25	1084330	474317	43.743	936931	418428	44.659	147399	55889	37.917
2016-04-26	1106615	678624	61.324	921532	576879	62.6	185083	101745	54.973
2016-04-27	1086552	672915	61.931	878715	553454	62.984	207837	119461	57.478
2016-04-28	1066626	694998	65.159	841933	555214	65.945	224693	139784	62.211
2016-04-29	1079856	701579	64.97	854740	556528	65.111	225116	145051	64.434
2016-04-30	1005141	603375	60.029	778704	470196	60.382	226437	133179	58.815
2016-05-01	922822	636170	68.937	703029	481636	68.509	219793	154534	70.309
2016-05-02	923637	624955	67.662	690843	472798	68.438	232794	152157	65.361
2016-05-03	912692	555316	60.844	668396	416447	62.305	244296	138869	56.845
2016-05-04	919118	587380	63.907	683132	446402	65.346	235986	140978	59.74
2016-05-05	889725	581806	65.392	659028	439989	66.763	230697	141817	61.473
2016-05-06	887489	534149	60.187	658611	407554	61.881	228878	126595	55.311
2016-05-07	851475	473762	55.64	628638	367472	58.455	222837	106290	47.699
2016-05-08	790803	266292	33.674	581512	207387	35.663	209291	58905	28.145
2016-05-09	807714	9267	1.147	590649	6183	1.047	217065	3084	1.421

Table 29: Six minutes system users minus 01:00:00, 01:30:00, 04:00:00 and 04:30:00

Date	Total play-backs	Affected play-backs	Affected play-backs %	Total online play-backs	Affected online play-backs	Affected online play-backs %	Total offline play-backs	Affected offline play-backs	Affected offline play-backs %
2016-01-21	5183365	4733	0.091	2887796	35	0.001	2295569	4698	0.205
2016-01-22	5699857	4737	0.083	3197499	32	0.001	2502358	4705	0.188
2016-01-23	5706073	4517	0.079	3320763	56	0.002	2385310	4461	0.187
2016-01-24	4990937	4364	0.087	2877218	38	0.001	2113719	4326	0.205
2016-01-25	5034490	4598	0.091	2775176	48	0.002	2259314	4550	0.201
2016-01-26	5211451	3825	0.073	2861114	32	0.001	2350337	3793	0.161
2016-01-27	5699874	4822	0.085	3115105	43	0.001	2584769	4779	0.185
2016-01-28	10716712	30827	0.288	5406227	81	0.001	5310485	30746	0.579
2016-01-29	10860619	23420	0.216	5522217	56	0.001	5338402	23364	0.438
2016-01-30	10008250	19929	0.199	5200705	77	0.001	4807545	19852	0.413
2016-01-31	8445037	15193	0.18	4380686	29	0.001	4064351	15164	0.373
2016-02-01	8595181	16261	0.189	4260810	55	0.001	4334371	16206	0.374
2016-02-02	8469929	14744	0.174	4153867	35	0.001	4316062	14709	0.341
2016-02-03	8386787	14463	0.172	4130617	51	0.001	4256170	14412	0.339
2016-02-04	8410214	13956	0.166	4128894	30	0.001	4281320	13926	0.325
2016-02-05	9001255	12552	0.139	4503223	34	0.001	4498032	12518	0.278
2016-02-06	8841003	10903	0.123	4623472	34	0.001	4217531	10869	0.258
2016-02-07	8375341	11646	0.139	4562874	51	0.001	3812467	11595	0.304
2016-02-08	8145940	12578	0.154	4244968	44	0.001	3900972	12534	0.321
2016-02-09	8439985	13191	0.156	4289622	44	0.001	4150363	13147	0.317
2016-02-10	8437553	12208	0.145	4261212	56	0.001	4176341	12152	0.291
2016-02-11	8748323	11819	0.135	4431643	34	0.001	4316680	11785	0.273
2016-02-12	9591865	11551	0.12	4932532	55	0.001	4659333	11496	0.247
2016-02-13	9207400	10506	0.114	4815322	32	0.001	4392078	10474	0.238
2016-02-14	52264508	155360	0.297	25683182	161	0.001	26581326	155199	0.584
2016-02-15	62315131	187722	0.301	28423017	190	0.001	33892114	187532	0.553
2016-02-16	62575347	192010	0.307	27216556	160	0.001	35358791	191850	0.543
2016-02-17	61635277	183367	0.298	26096222	134	0.001	35539055	183233	0.516
2016-02-18	58176702	166794	0.287	24279133	90	0.0	33897569	166704	0.492
2016-02-19	57453384	166805	0.29	23863079	100	0.0	33590305	166705	0.496
2016-02-20	51238240	139806	0.273	21695419	74	0.0	29542821	139732	0.473
2016-02-21	44012913	116241	0.264	19017377	113	0.001	24995536	116128	0.465
2016-02-22	48123726	129388	0.269	20139829	75	0.0	27983897	129313	0.462
2016-02-23	47818784	126280	0.264	19908725	76	0.0	27910059	126204	0.452
2016-02-24	19205376	42558	0.222	8020004	62	0.001	11185372	42496	0.38
2016-02-25	19155488	40863	0.213	7933048	54	0.001	11222440	40809	0.364
2016-02-26	19895000	41890	0.211	8316062	62	0.001	11578938	41828	0.361
2016-02-27	18410754	33902	0.184	7817765	89	0.001	10592989	33813	0.319
2016-02-28	16341019	27969	0.171	7006815	61	0.001	9334204	27908	0.299
2016-02-29	17041782	34076	0.2	7049968	91	0.001	9991814	33985	0.34
2016-03-01	17519578	34690	0.198	7264171	72	0.001	10255407	34618	0.338
2016-03-02	17260480	33083	0.192	7182545	62	0.001	10077935	33021	0.328
2016-03-03	17326476	32095	0.185	7175051	112	0.002	10151425	31983	0.315
2016-04-18	13094984	24745	0.189	5480281	43	0.001	7614703	24702	0.324
2016-04-19	13228953	26007	0.197	5561693	91	0.002	7667260	25916	0.338
2016-04-20	13716969	23802	0.174	5943181	72	0.001	7773788	23730	0.305
2016-04-21	13592572	21253	0.156	6080560	37	0.001	7512012	21216	0.282
2016-04-22	15716545	23430	0.149	7204431	65	0.001	8512114	23365	0.274
2016-04-23	14539943	20741	0.143	6686559	116	0.002	7853384	20625	0.263
2016-04-24	32844244	8884732	27.051	16533941	4154960	25.13	16310303	4729772	28.999
2016-04-25	61648530	37244251	60.414	27532332	15483150	56.236	34116198	21761101	63.785
2016-04-26	51762664	30027656	58.01	23271706	12924148	55.536	28490958	17103508	60.031
2016-04-27	51443095	30890484	60.048	22441805	12790978	56.996	29001290	18099506	62.409
2016-04-28	49571047	30583184	61.696	21060520	12196310	57.911	28510527	18386874	64.492
2016-04-29	45740028	28087305	61.406	19304866	11067972	57.333	26435162	17019333	64.381
2016-04-30	44747668	28205621	63.033	18482843	10821692	58.55	26264825	17383929	66.187
2016-05-01	38826732	26924110	69.344	16407601	10690625	65.157	22419131	16233485	72.409
2016-05-02	36971583	24015225	64.956	15561500	9739413	62.587	21410083	14275812	66.678
2016-05-03	34043783	19841450	58.282	14283511	7939668	55.586	19760272	11901782	60.231
2016-05-04	32862327	18701391	56.908	14013298	7602803	54.254	18849029	11098588	58.881
2016-05-05	31535242	17950298	56.921	13427299	7319756	54.514	18107943	10630542	58.707
2016-05-06	30227071	15727666	52.032	12798897	6397223	49.983	17428174	9330443	53.537
2016-05-07	26738540	13342121	49.898	11477044	5760631	50.193	15261496	7581490	49.677
2016-05-08	20337761	5341822	26.266	8893020	2327690	26.174	11444741	3014132	26.336
2016-05-09	19254690	33567	0.174	8408779	96	0.001	10845911	33471	0.309

A ADDITIONAL MODULO SIX SUMMARIES

Table 30: Six minutes playbacks minus 01:00:00, 01:30:00, 04:00:00 and 04:30:00

Date	Online users online play-backs	Online users offline play-backs	Offline users online play-backs	Offline users offline play-backs	Affected play-backs from albums	Affected play-backs from albums %	Affected online play-backs from albums	Affected offline play-backs from albums
2016-01-21	35	2855	0	1843	0	0.0	0	0
2016-01-22	32	2870	0	1835	0	0.0	0	0
2016-01-23	56	2855	0	1606	0	0.0	0	0
2016-01-24	38	2676	0	1650	0	0.0	0	0
2016-01-25	48	2736	0	1814	0	0.0	0	0
2016-01-26	32	2298	0	1495	0	0.0	0	0
2016-01-27	43	3215	0	1564	0	0.0	0	0
2016-01-28	81	26818	0	3928	0	0.0	0	0
2016-01-29	56	15804	0	7560	0	0.0	0	0
2016-01-30	77	11464	0	8388	0	0.0	0	0
2016-01-31	29	8285	0	6879	0	0.0	0	0
2016-02-01	55	8655	0	7551	0	0.0	0	0
2016-02-02	35	7711	0	6998	0	0.0	0	0
2016-02-03	51	7445	0	6967	0	0.0	0	0
2016-02-04	30	6883	0	7043	0	0.0	0	0
2016-02-05	34	6974	0	5544	0	0.0	0	0
2016-02-06	34	6898	0	3971	0	0.0	0	0
2016-02-07	51	8665	0	2930	0	0.0	0	0
2016-02-08	44	9160	0	3374	0	0.0	0	0
2016-02-09	44	8524	0	4623	0	0.0	0	0
2016-02-10	56	7795	0	4357	0	0.0	0	0
2016-02-11	34	6871	0	4914	0	0.0	0	0
2016-02-12	55	6648	0	4848	0	0.0	0	0
2016-02-13	32	6393	0	4081	0	0.0	0	0
2016-02-14	161	120781	0	34418	88861	57.197	108	88753
2016-02-15	190	116066	0	71466	120972	64.442	130	120842
2016-02-16	160	113137	0	78713	119967	62.48	97	119870
2016-02-17	134	106400	0	76833	106767	58.226	67	106700
2016-02-18	90	96159	0	70545	90379	54.186	50	90329
2016-02-19	100	95645	0	71060	81417	48.81	39	81378
2016-02-20	74	83021	0	56711	58230	41.651	22	58208
2016-02-21	113	66605	0	49523	44272	38.086	27	44245
2016-02-22	75	75557	0	53756	52675	40.711	20	52655
2016-02-23	76	74028	0	52176	47532	37.64	24	47508
2016-02-24	62	23927	0	18569	25800	60.623	27	25773
2016-02-25	54	22978	0	17831	23821	58.295	14	23807
2016-02-26	62	24185	0	17643	24160	57.675	21	24139
2016-02-27	89	18637	0	15176	17695	52.195	10	17685
2016-02-28	61	15543	0	12365	14002	50.063	11	13991
2016-02-29	91	18646	0	15339	18181	53.354	14	18167
2016-03-01	72	19308	0	15310	17618	50.787	10	17608
2016-03-02	62	17933	0	15088	16245	49.104	8	16237
2016-03-03	112	18021	0	13962	15422	48.051	13	15409
2016-04-18	43	16786	0	7916	0	0.0		
2016-04-19	91	16642	0	9274	0	0.0		
2016-04-20	72	17134	0	6596	0	0.0		
2016-04-21	37	14969	0	6247	0	0.0		
2016-04-22	65	17188	0	6177	0	0.0		
2016-04-23	116	14080	0	6545	0	0.0		
2016-04-24	4154960	4581739	0	148033	4487452	50.507		
2016-04-25	15483150	17676431	0	4084670	31011326	83.265		
2016-04-26	12924148	13003652	0	4099856	17056443	56.802		
2016-04-27	12790978	12990426	0	5109080	18277540	59.169		
2016-04-28	12196310	12814832	0	5572042	17105968	55.933		
2016-04-29	11067972	11818393	0	5200940	14687643	52.293		
2016-04-30	10821692	11658322	0	5725607	17426606	61.784		
2016-05-01	10690625	10691445	0	5542040	13779847	51.18		
2016-05-02	9739413	9335101	0	4940711	10853394	45.194		
2016-05-03	7939668	7597497	0	4304285	7735017	38.984		
2016-05-04	7602803	7181643	0	3916945	6226608	33.295		
2016-05-05	7319756	6955923	0	3674619	5080204	28.302		
2016-05-06	6397223	6249592	0	3080851	3491249	22.198		
2016-05-07	5760631	5260916	0	2320574	1480617	11.097		
2016-05-08	2327690	2065222	0	948910	670915	12.56		
2016-05-09	96	21549	0	11922	5668	16.886		

Table 31: Six minutes affected users playbacks minus 01:00:00, 01:30:00, 04:00:00 and 04:30:00

B Code for serial analysis method

A code for many of the serial analysis methods described in Section 4. It mainly consists of a for-loop over all the files we received, executing the same analysis methods over all the files. For each file it will convert the columns into a `datetime` variable or treat it as a categorical variable.

Listing 6: Shared code for serial analysis methods

```
1  #!/usr/bin/env python
2
3  from __future__ import print_function
4  from collections import Counter
5  import pandas as pd
6
7  def main(argv):
8      print('Reading file %s' % argv[0])
9      df = pd.read_csv(argv[0], sep=';')
10     df['timestamp'] = pd.to_datetime(df['timestamp'], format='%Y-%m-%d
        %H:%M:%S.%f', errors='ignore')
11     df['countrycode'] = df.countrycode.astype('category')
12     df['systemuserid'] = df.systemuserid.astype('category')
13     df['trackid'] = df.trackid.astype('category')
14     df['offlineplay'] = df.offlineplay.astype('category')
15
16     #####
17     # Analysis 2.1 - 2.4 code goes here #
18     #####
19
20 if __name__ == "__main__":
21     # Suppress scientific notation in output
22     pd.set_option('display.float_format', lambda x: '%.3f' % x)
23     for arguments in [
24         ['all_data_ny_log2016-01-21.csv', '01_21.csv'],
25         ['all_data_ny_log2016-01-22.csv', '01_22.csv'],
26         ['all_data_ny_log2016-01-23.csv', '01_23.csv'],
27         ['all_data_ny_log2016-01-24.csv', '01_24.csv'],
28         ['all_data_ny_log2016-01-25.csv', '01_25.csv'],
29         ['all_data_ny_log2016-01-26.csv', '01_26.csv'],
30         ['all_data_ny_log2016-01-27.csv', '01_27.csv'],
31         ['all_data_ny_log2016-01-28.csv', '01_28.csv'],
32         ['all_data_ny_log2016-01-29.csv', '01_29.csv'],
33         ['all_data_ny_log2016-01-30.csv', '01_30.csv'],
34         ['all_data_ny_log2016-01-31.csv', '01_31.csv'],
35         ['all_data_ny_log2016-02-01.csv', '02_01.csv'],
36         ['all_data_ny_log2016-02-02.csv', '02_02.csv'],
37         ['all_data_ny_log2016-02-03.csv', '02_03.csv'],
38         ['all_data_ny_log2016-02-04.csv', '02_04.csv'],
39         ['all_data_ny_log2016-02-05.csv', '02_05.csv'],
```

```
40 ['all_data_ny_log2016-02-06.csv', '02_06.csv'],
41 ['all_data_ny_log2016-02-07.csv', '02_07.csv'],
42 ['all_data_ny_log2016-02-08.csv', '02_08.csv'],
43 ['all_data_ny_log2016-02-09.csv', '02_09.csv'],
44 ['all_data_ny_log2016-02-10.csv', '02_10.csv'],
45 ['all_data_ny_log2016-02-11.csv', '02_11.csv'],
46 ['all_data_ny_log2016-02-12.csv', '02_12.csv'],
47 ['all_data_ny_log2016-02-13.csv', '02_13.csv'],
48 ['all_data_2016-02-14.csv', '02_14.csv'],
49 ['all_data_2016-02-15.csv', '02_15.csv'],
50 ['all_data_2016-02-16.csv', '02_16.csv'],
51 ['all_data_2016-02-17.csv', '02_17.csv'],
52 ['all_data_2016-02-18.csv', '02_18.csv'],
53 ['all_data_2016-02-19.csv', '02_19.csv'],
54 ['all_data_2016-02-20.csv', '02_20.csv'],
55 ['all_data_2016-02-21.csv', '02_21.csv'],
56 ['all_data_2016-02-22.csv', '02_22.csv'],
57 ['all_data_2016-02-23.csv', '02_23.csv'],
58 ['all_data_2016-02-24.csv', '02_24.csv'],
59 ['all_data_2016-02-25.csv', '02_25.csv'],
60 ['all_data_2016-02-26.csv', '02_26.csv'],
61 ['all_data_2016-02-27.csv', '02_27.csv'],
62 ['all_data_2016-02-28.csv', '02_28.csv'],
63 ['all_data_2016-02-29.csv', '02_29.csv'],
64 ['all_data_2016-03-01.csv', '03_01.csv'],
65 ['all_data_2016-03-02.csv', '03_02.csv'],
66 ['all_data_2016-03-03.csv', '03_03.csv'],
67 ['all_data_ny_log2016-04-18.csv', '04_18.csv'],
68 ['all_data_ny_log2016-04-19.csv', '04_19.csv'],
69 ['all_data_ny_log2016-04-20.csv', '04_20.csv'],
70 ['all_data_ny_log2016-04-21.csv', '04_21.csv'],
71 ['all_data_ny_log2016-04-22.csv', '04_22.csv'],
72 ['all_data_ny_log2016-04-23.csv', '04_23.csv'],
73 ['all_data_ny_log2016-04-24.csv', '04_24.csv'],
74 ['all_data_ny_log2016-04-25.csv', '04_25.csv'],
75 ['all_data_ny_log2016-04-26.csv', '04_26.csv'],
76 ['all_data_ny_log2016-04-27.csv', '04_27.csv'],
77 ['all_data_ny_log2016-04-28.csv', '04_28.csv'],
78 ['all_data_ny_log2016-04-29.csv', '04_29.csv'],
79 ['all_data_ny_log2016-04-30.csv', '04_30.csv'],
80 ['all_data_ny_log2016-05-01.csv', '05_01.csv'],
81 ['all_data_ny_log2016-05-02.csv', '05_02.csv'],
82 ['all_data_ny_log2016-05-03.csv', '05_03.csv'],
83 ['all_data_ny_log2016-05-04.csv', '05_04.csv'],
84 ['all_data_ny_log2016-05-05.csv', '05_05.csv'],
85 ['all_data_ny_log2016-05-06.csv', '05_06.csv'],
86 ['all_data_ny_log2016-05-07.csv', '05_07.csv'],
```

```
87     ['all_data_ny_log2016-05-08.csv', '05_08.csv'],  
88     ['all_data_ny_log2016-05-09.csv', '05_09.csv'],  
89 ]:  
90     main(arguments)
```

C Code for analysis method 2.1 - 2.3

The main-body of this script can be found in Appendix B.

Listing 7: Analysis method 2 code

```
1 print('Find occurrences of all identical trackid with the same
   timestamp for systemuserid')
2 df_all_duplicates = df[df.duplicated(subset=['timestamp', '
   systemuserid', 'trackid'], keep=False)]
3 df_all_duplicates.sort_values(by='timestamp').reset_index().drop(['
   index'], axis=1).to_csv('final/intermediate/A2_all_duplicates_' +
   argv[1], sep=';', date_format='%Y-%m-%d %H:%M:%S.%f', index=
   False)
4 df_all_duplicates.reset_index(level=0, inplace=True)
5 print('Find occurrences of two identical trackid with the same
   timestamp for systemuserid')
6 # AND Find occurrences of more than two identical trackid with the
   same timestamp for systemuserid
7 duplicates_groups = (df_all_duplicates.groupby(['timestamp', '
   systemuserid', 'trackid'], as_index=False).size() == 2).to_frame(
   name='two').reset_index()
8 duplicates_groups = duplicates_groups.sort_values(by=['timestamp', '
   systemuserid', 'trackid'])
9 df_all_duplicates = df_all_duplicates.sort_values(by=['timestamp', '
   systemuserid', 'trackid'])
10 df_all_duplicates['two'] = None
11 i = 0
12 for n in df_all_duplicates.itertuples():
13     t = duplicates_groups.loc[i]
14     if n[2] == t['timestamp'] and n[4] == t['systemuserid'] and n[5]
       == t['trackid']:
15         df_all_duplicates.at[n[0], 'two'] = t['two']
16     else:
17         i += 1
18         t = duplicates_groups.loc[i]
19         df_all_duplicates.at[n[0], 'two'] = t['two']
20
21 two = df_all_duplicates.loc[df_all_duplicates['two'] == True]
22 three = df_all_duplicates.loc[df_all_duplicates['two'] == False]
23 # Export to CSV
24 two.sort_values(by='timestamp').reset_index().drop(['index'], axis
   =1).to_csv('final/A2_two_duplicates/A2_two_duplicates_' + argv
   [1], sep=';', index=False)
25 three.sort_values(by='timestamp').reset_index().drop(['index'], axis
   =1).to_csv('final/A2_three_or_more_duplicates/
   A2_three_or_more_duplicates_' + argv[1], sep=';', index=False)
```

D Code for auxiliary analysis method 2.4 - 2.6

Python scripts without the shared main-body for serial execution code, which can be found in Appendix B. This code is an intermediate step, which only extracts the count of all occurrences of unequal duplicates. The code found in Appendix E is the final step of separating between both two and three and more unequal duplicates.

Listing 8: Analysis method 2.4 - 2.6 code

```
1 # Find occurrences of all unequal trackid with the same timestamp
  for systemuserid
2 df_all_duplicates = df[df.duplicated(subset=['timestamp', '
  systemuserid'], keep=False)]
3 df_all_duplicates_groups = df_all_duplicates.groupby(['timestamp', '
  systemuserid', 'trackid'], as_index=False).size().to_frame(name='
  size').reset_index()
4 df_all_duplicates['count'] = None
5
6 df_all_duplicates = df_all_duplicates.sort_values(by=['timestamp', '
  systemuserid', 'trackid'])
7 df_all_duplicates_groups = df_all_duplicates_groups.sort_values(by=['
  timestamp', 'systemuserid', 'trackid'])
8
9 k = 0
10 for i in range(len(df_all_duplicates_groups)):
11     for j in range(k, len(df_all_duplicates)):
12         if (df_all_duplicates_groups.iat[i, 0] == df_all_duplicates.iat[
13             j, 0]) and (df_all_duplicates_groups.iat[i, 1] ==
14                 df_all_duplicates.iat[j, 2]) and (df_all_duplicates_groups.
15                     iat[i, 2] == df_all_duplicates.iat[j, 3]):
16             df_all_duplicates.iat[j, 5] = df_all_duplicates_groups.iat[i,
17                 3]
18         else:
19             # Next group
20             break
21         df_all_duplicates.iat[j, 5] = df_all_duplicates_groups.iat[i +
22             1, 3]
23     k += 1
24 if i < 100 or i % 10000 == 0:
25     print(i, len(df_all_duplicates_groups))
26
27 df_all_duplicates.sort_values(by='timestamp').reset_index().drop(['
  index'], axis=1).to_csv('final/intermediate/
  A2_all_unequal_duplicates_count_' + argv[1], sep=';', index=False
  )
```

E Code for final analysis method 2.4 - 2.6

Appendix D was an intermediate step to extract all unequal duplicates. This code will use the results from this intermediate step to separate two or more unequal duplicates into separate files.

Listing 9: Analysis method 2.4 - 2.6 code final

```
1  #!/usr/bin/env python
2
3  from __future__ import print_function
4  import multiprocessing as mp
5  import pandas as pd
6  import os
7
8  dataset = [
9      ['A2_all_unequal_duplicates_count_01_21.csv', '01_21.csv'],
10     ['A2_all_unequal_duplicates_count_01_22.csv', '01_22.csv'],
11     # ... (list reduced)
12     ['A2_all_unequal_duplicates_count_05_08.csv', '05_08.csv'],
13     ['A2_all_unequal_duplicates_count_05_09.csv', '05_09.csv'],
14 ]
15
16 def mp_worker(argv):
17     pid = os.getpid()
18     print('Reading file %s (PID: %s)' % (argv[0], pid))
19     df = pd.read_csv('final/intermediate/' + argv[0], sep=';')
20     df['timestamp'] = pd.to_datetime(df['timestamp'], format='%Y-%m-%d
21     %H:%M:%S.%f', errors='ignore')
22     df['countrycode'] = df.countrycode.astype('category')
23     df['systemuserid'] = df.systemuserid.astype('category')
24     df['trackid'] = df.trackid.astype('category')
25     df['offlineplay'] = df.offlineplay.astype('category')
26
27     df_all_groups = df.groupby(['timestamp', 'systemuserid', 'trackid'
28     ]).size().to_frame(name='count').reset_index()
29     df_all_groups = df_all_groups.groupby(['timestamp', 'systemuserid'
30     ]).size().to_frame(name='count').reset_index()
31     df_all_groups = df_all_groups[df_all_groups['count'] > 1]
32
33     df_keep = df[(df['timestamp'].isin(df_all_groups['timestamp']).
34     unique()) & df['systemuserid'].isin(df_all_groups['
35     systemuserid'].unique())].reset_index(drop=True)
36     df_keep_groups = df_keep.groupby(['timestamp', 'systemuserid']).
37     size().to_frame(name='count').reset_index()
38     df_keep['count'] = 0
39
40     df_keep = df_keep.sort_values(by=['timestamp', 'systemuserid']).
41     reset_index(drop=True)
```



```
35 df_keep_groups = df_keep_groups.sort_values(by=['timestamp', '
    systemuserid']).reset_index(drop=True)
36
37 i = 0
38 for j in range(len(df_keep_groups)):
39     for k in range(i, len(df_keep)):
40         if df_keep_groups.iat[j, 0] == df_keep.iat[k, 0] and
            df_keep_groups.iat[j, 1] == df_keep.iat[k, 2]:
41             df_keep.iat[k, 5] = df_keep_groups.iat[j, 2]
42             i += 1
43         else:
44             break
45     if j % 10000 == 0:
46         print('%s/%s (PID: %s)' % (j, len(df_keep_groups), pid))
47 two = df_keep[df_keep['count'] == 2]
48 three = df_keep[df_keep['count'] > 2]
49
50 # Export to CSV
51 two.sort_values(by='timestamp').reset_index().drop(['index', '
    count'], axis=1).to_csv('final/A2_two_unequal_duplicates/
    A2_two_unequal_duplicates_' + argv[1], sep=';', index=False)
52 three.sort_values(by='timestamp').reset_index().drop(['index', '
    count'], axis=1).to_csv('final/
    A2_three_or_more_unequal_duplicates/
    A2_three_or_more_unequal_duplicates_' + argv[1], sep=';', index
    =False)
53
54 if __name__ == "__main__":
55     # Suppress scientific notation in output
56     pd.set_option('display.float_format', lambda x: '%.3f' % x)
57
58     pool = mp.Pool(processes=2)
59     results = [pool.map_async(func=mp_worker, iterable=dataset,
        chunksize=1)]
60     result = [p.get() for p in results]
61     pool.close()
62     pool.join()
```

F Code for analysis method 9

Listing 10: Analysis method 9 code

```
1  #!/usr/bin/env python
2
3  from __future__ import print_function
4  import pandas as pd
5  import multiprocessing as mp
6  import os
7
8  def mp_worker(df_local):
9      pid = os.getpid()
10     df_local['keep'] = False
11     df_local['sms'] = df_local['timestamp'].apply(lambda row: row
12         [-6:])
13     df_local['timestamp'] = pd.to_datetime(df_local['timestamp'],
14         format='%Y-%m-%d %H:%M:%S.%f', errors='coerce')
15     df_local = df_local[df_local['timestamp'].notnull()].sort_values(
16         by=['systemuserid', 'sms', 'trackid']).reset_index(drop=True)
17     similar_sms_trackid = df_local.groupby(['systemuserid', 'sms', '
18         trackid'], as_index=False).size().to_frame(name='count').
19         reset_index()
20     similar_sms_trackid = similar_sms_trackid[similar_sms_trackid['
21         count'] > 1].reset_index(drop=True)
22     p_count = 0
23     i = 0
24     j = 0
25     while j < len(df_local):
26         if (df_local.iat[j, 2] == similar_sms_trackid.iat[i, 0]) and (
27             df_local.iat[j, 6] == similar_sms_trackid.iat[i, 1]) and (
28                 df_local.iat[j, 3] == similar_sms_trackid.iat[i, 2]):
29             count = similar_sms_trackid.iat[i, 3]
30             for k in range(count):
31                 for l in range(j + k, j + count):
32                     # Different trackid
33                     if not df_local.iat[j + k, 3] == df_local.iat[l, 3]:
34                         break
35                     # Avoid duplicates
36                     elif (df_local.iat[j + k, 0] - df_local.iat[l, 0]).seconds
37                         > 0:
38                         # Check divisible by six minutes (in nanoseconds)
39                         if (df_local.iat[j + k, 0] - df_local.iat[l, 0]).value %
40                             360000000000 == 0:
41                             df_local.iat[j + k, 5] = True
42                             df_local.iat[l, 5] = True
43             # Jump count forward, -1 to account for +1 at end of loop
44             j += count - 1
```

```
35     if i < len(similar_sms_trackid) - 1:
36         i += 1
37     elif i == len(similar_sms_trackid) - 1:
38         break
39     if j >= p_count:
40         print('%s/%s (PID: %s)' % (j, len(df_local), pid))
41         p_count += 100000
42         j += 1
43 df_local = df_local[df_local['keep'] == True].drop(['sms', 'keep'
44 ], axis=1).reset_index(drop=True)
45 print('Done (PID: %s)' % (pid))
46 return df_local
47
48 if __name__ == "__main__":
49     # Suppress scientific notation in output
50     pd.set_option('display.float_format', lambda x: '%.3f' % x)
51     for arguments in [
52         ['all_data_ny_log2016-01-21.csv', '01_21.csv'],
53         ['all_data_ny_log2016-01-22.csv', '01_22.csv'],
54         # ... (list reduced)
55         ['all_data_ny_log2016-05-08.csv', '05_08.csv'],
56         ['all_data_ny_log2016-05-09.csv', '05_09.csv'],
57     ]:
58         print('Working on file %s' % (arguments[0]))
59         df = pd.read_csv(arguments[0], sep=';')
60         df['countrycode'] = df.countrycode.astype('category')
61         df['systemuserid'] = df.systemuserid.astype('category')
62         df['trackid'] = df.trackid.astype('category')
63         df['offlineplay'] = df.offlineplay.astype('category')
64
65         # First reduce the dataset by removing systemuserid which only
66         # occur once
67         users_appear_once = df.groupby(['systemuserid'], as_index=False)
68             .size().to_frame(name='count').reset_index()
69         df = df[~df['systemuserid'].isin(users_appear_once[
70             users_appear_once['count'] == 1]['systemuserid'].values)]
71         df = df.sort_values(by='systemuserid').reset_index(drop=True)
72
73         # Find initial split values
74         process_start = [int(i * round(len(df) / 16)) for i in range(16)
75             ]
76         # Ensure that the split values occur at new systemuserid values
77         for i in range(1, len(process_start)):
78             for j in range(process_start[i], len(df)):
79                 if df.iat[process_start[i], 2] != df.iat[j, 2]:
80                     process_start[i] = j
81                     break
```

```
77     process_start.append(len(df))
78
79     dataset = [df[process_start[i - 1]:process_start[i]].reset_index
80               (drop=True) for i in range(1, len(process_start))]
81     pool = mp.Pool(processes=4)
82     results = [pool.map_async(func=mp_worker, iterable=dataset,
83                             chunksize=1)]
84     result = [p.get() for p in results]
85     pool.close()
86     pool.join()
87
88     new = pd.concat([result[0][i] for i in range(len(result[0]))],
89                   axis=0, ignore_index=True)
90     new.sort_values(by='timestamp').to_csv('final/A9_six_minutes/
91     A9_six_minutes_' + arguments[1], sep=';', index=False)
```

G Log files received

This list contains all the files we received in February, 2018. The MD5 hash was the first thing done to the files once plugging in the external hard disk. Done through Windows PowerShell with the command: `Get-Filehash -algorithm md5 *`

MD5	Filename	Size
5FF09DFCEA07EFD1ED79CEDDBE8C9819	all_data.ny_log2016-01-21.csv	256 MB
2A31121732A81F14A5DE02A1ACACD689	all_data.ny_log2016-01-22.csv	281 MB
A0884E9D5E08DCFC293D7769FBAA1498	all_data.ny_log2016-01-23.csv	281 MB
1070E957C50C72592A91D8B3FF5555CF	all_data.ny_log2016-01-24.csv	246 MB
41FD55EFD25E5B8EC8F29A2DCBC681F	all_data.ny_log2016-01-25.csv	249 MB
3F66140DA4D1E34FBC1F7ADA1CED3B8F	all_data.ny_log2016-01-26.csv	257 MB
B47120DF0F95853C221C94E272AAC7EE	all_data.ny_log2016-01-27.csv	281 MB
239B4896C0B75543696BA369C86FAA4F	all_data.ny_log2016-01-28.csv	530 MB
017AD8ACF199F7BD341638FE19B414C5	all_data.ny_log2016-01-29.csv	537 MB
7F14CBCA9E364A4408B4EA6825877F2F	all_data.ny_log2016-01-30.csv	495 MB
1B7F196EA65A1D1732EF8DE360AB54D4	all_data.ny_log2016-01-31.csv	417 MB
C99B5F4A8B9068A8DB7B50CDA54B2476	all_data.ny_log2016-02-01.csv	425 MB
8F8E52586189E8B2A14F8065EB77FOC4	all_data.ny_log2016-02-02.csv	419 MB
A6128103598A1164F6ABD7F10388855D	all_data.ny_log2016-02-03.csv	414 MB
CB4106FFEFB3AD6B69D1D2DE6E33D00F	all_data.ny_log2016-02-04.csv	416 MB
6B8B81147B09CDD7D6667D5C59EA6721	all_data.ny_log2016-02-05.csv	445 MB
90705EE8E47FE18D8EDD69C36EE09413	all_data.ny_log2016-02-06.csv	437 MB
C01ADD9A4ED71C31CF0DE3BE094C4BF5	all_data.ny_log2016-02-07.csv	414 MB
2D71FC08639F8257E2C6654A923D8544	all_data.ny_log2016-02-08.csv	403 MB
0D88D046713163CAFE362326DDA79BD	all_data.ny_log2016-02-09.csv	417 MB
FB0FD2988E99B81BC787EAC7DE9AF444	all_data.ny_log2016-02-10.csv	417 MB
C7EA904726C2B9A291E0E578F3230B76	all_data.ny_log2016-02-11.csv	432 MB
F1A5E4588AF67B0994393E1AB09B1DD4	all_data.ny_log2016-02-12.csv	474 MB
EC3D06A81F12990BB0B04EAD9A153E57	all_data.ny_log2016-02-13.csv	455 MB
3324BE790A4ED71F88336DFC77924DOB	all_data.ny_log2016-04-18.csv	647 MB
BA9A65972ED5E5904FB363454CBD6CEA	all_data.ny_log2016-04-19.csv	654 MB
356931F967109FF4A6B8124DE8FE8F96	all_data.ny_log2016-04-20.csv	678 MB
E29C4AACA32705616FFA6D36465F255E	all_data.ny_log2016-04-21.csv	671 MB
2C5F054E0C13F5F35084A44E5D8C60B0	all_data.ny_log2016-04-22.csv	775 MB
644BF9E2D1534DE499F40A000B14368D	all_data.ny_log2016-04-23.csv	717 MB
9024A830894492A67B49C82CC4C2C5E8	all_data.ny_log2016-04-24.csv	1,6 GB
C81C745B927AC23DB7D528CFF2259A09	all_data.ny_log2016-04-25.csv	3,0 GB
504BA4F2670B29598CFF2727AA171C51	all_data.ny_log2016-04-26.csv	2,6 GB

MD5	Filename	Size
714D233DF96B1ACF40C9E09CE81F7ACD	all_data_ny_log2016-04-27.csv	2,5 GB
87E6E7F3F43B65143622DCDAB7AC3F05	all_data_ny_log2016-04-28.csv	2,4 GB
A30AAE4160B882781C3403E8FF9F2044	all_data_ny_log2016-04-29.csv	2,3 GB
D5C57D3416158FBB14C2BEF4022114EA	all_data_ny_log2016-04-30.csv	2,2 GB
68363C66911EA558E0163328E453A325	all_data_ny_log2016-05-01.csv	1,9 GB
CD1E635D2A6E81C7B6097477A78E88FA	all_data_ny_log2016-05-02.csv	1,8 GB
492EC212048443402C3115C97F756BD6	all_data_ny_log2016-05-03.csv	1,7 GB
9534403274C1826DD01D50B9C9A31E89	all_data_ny_log2016-05-04.csv	1,6 GB
7A9A6F36FE86BB4C78F1F222500CB3FF	all_data_ny_log2016-05-05.csv	1,6 GB
05D45852C53B1A9A885670D8B8D60431	all_data_ny_log2016-05-06.csv	1,5 GB
96C5BDCC753DC7F8E0CBA662CC14A1EE	all_data_ny_log2016-05-07.csv	1,3 GB
D1A16B004FAAD6F45078AD2EFD93B72B	all_data_ny_log2016-05-08.csv	1005 MB
FOE67C7FE977FAC172C71F508B8DE15A	all_data_ny_log2016-05-09.csv	952 MB
15844E56C5F25678D46E235C3C636F1A	all_data_2016-02-14.csv	2,4 GB
C44491BDA1D0B3E67990521900261210	all_data_2016-02-15.csv	2,8 GB
B8F499213DE320A57FF07E9BFFD294EA	all_data_2016-02-16.csv	2,8 GB
754FD2E8B8703BE445D941BC93DA865E	all_data_2016-02-17.csv	2,8 GB
B46C3588CB933321FC60E4CB751932E6	all_data_2016-02-18.csv	2,6 GB
E34FF092CE7EE2DAFB700FC30EABABF7	all_data_2016-02-19.csv	2,6 GB
029E16DF53033193DAEBC05C70883744	all_data_2016-02-20.csv	2,3 GB
617086D65FC1BFB48C852AF98E93DFA2	all_data_2016-02-21.csv	2,0 GB
70AE5B339F9742C143592AFE7EEF08F7	all_data_2016-02-22.csv	2,2 GB
83BEE988DA7CEDADAB400FC36EC15EC1	all_data_2016-02-23.csv	2,2 GB
236D2975426A0AC097EE52E0D1AF9CC3	all_data_2016-02-24.csv	877 MB
649ECD5B0DA056A81B7225FCC1E6B09F	all_data_2016-02-25.csv	874 MB
D4F7BBACABDF492EACC891F46B04CC6D	all_data_2016-02-26.csv	908 MB
6075D0E6AFA1EAA50C0BF9550C839A36	all_data_2016-02-27.csv	840 MB
461D812F3AB5878009A0BAD656D53AD6	all_data_2016-02-28.csv	746 MB
12F1C64439BDD647DOECE2B145E0CA40	all_data_2016-02-29.csv	778 MB
A16AA3CC6566E2E41F614C971B5C7A9D	all_data_2016-03-01.csv	800 MB
6E26DFB51822D068262D916FCCCB981A	all_data_2016-03-02.csv	788 MB
BE0841E0C8D1DB2FA314DB74762234B1	all_data_2016-03-03.csv	791 MB