Data Preprocessing

Import Libraries and Trace Generation Data generated from the SQL Server Profiler

In [1]:
```
import pandas as pd
import numpy as np
```

In [2]:
```
data = pd.read_csv('./queries_copy.csv',parse_dates=['StartTime','EndTime'])
dataCopy = data.copy()

dataCopy
```

Out[2]:

	RowNumber	EventClass	TextData	ApplicationName	LoginName	ClientPro
0	0	65528	NaN	NaN	NaN	
1	1	65534	NaN	NaN	NaN	
2	2	12	select * from Weather.dbo.weather	Python	temp	
3	3	12	select * from Telecom.dbo.telecom_users	Python	temp	
4	4	12	insert into Telecom.dbo.telecom_users values (...	Python	temp	
...	...	...	...	...	...	
3043	3043	12	select * from Telecom.dbo.telecom_users	Python	temp22	1
3044	3044	12	insert into Telecom.dbo.telecom_users values (...	Python	temp22	1
3045	3045	12	use Weather select top 1000 * from weather whe...	Python	temp22	1
3046	3046	12	use Telecom select top 1000 * from telecom_use...	Python	temp22	1
3047	3047	65533	NaN	NaN	NaN	

3048 rows × 26 columns

Handling missing values

In [3]:
```
dataCopy.isna().sum()
```

Out[3]:
```
RowNumber          0
EventClass         0
TextData           3
```

```
ApplicationName        3
LoginName              3
ClientProcessID     1052
SPID                   3
StartTime              1
CPU                    3
Reads                  3
Writes                 3
Duration               3
EndTime                3
DatabaseID             3
DatabaseName           3
Error                  3
EventSequence          3
GroupID                3
HostName               3
LoginSid               3
RequestID              3
RowCounts              3
ServerName             3
SessionLoginName       3
TransactionID       2080
XactSequence           3
dtype: int64
```

In [4]:

```
dataCopy['ClientProcessID'] = dataCopy['ClientProcessID'].fillna(0)
dataCopy['TransactionID'] = dataCopy['TransactionID'].fillna(0)
```

In [5]:

```
dataCopy.isna().sum()
```

Out[5]:

```
RowNumber           0
EventClass          0
TextData            3
ApplicationName     3
LoginName           3
ClientProcessID     0
SPID                3
StartTime           1
CPU                 3
Reads               3
Writes              3
Duration            3
EndTime             3
DatabaseID          3
DatabaseName        3
Error               3
EventSequence       3
GroupID             3
HostName            3
LoginSid            3
RequestID           3
RowCounts           3
ServerName          3
SessionLoginName    3
TransactionID       0
XactSequence        3
dtype: int64
```

In [6]:

```
dataCopy.dropna(inplace=True)
dataCopy.reset_index(drop=True, inplace=True)
dataCopy
```

Out[6]:

	RowNumber	EventClass	TextData	ApplicationName	LoginName	ClientPrc
0	2	12	select * from Weather.dbo.weather	Python	temp	
1	3	12	select * from Telecom.dbo.telecom_users	Python	temp	
2	4	12	insert into Telecom.dbo.telecom_users values (...	Python	temp	
3	5	12	select * from Telecom.dbo.telecom_users	Python	temp	
4	6	12	insert into Weather.dbo.weather values (42.45,...	Python	temp	
...	...	...	...	...	...	
3040	3042	12	select * from Weather.dbo.weather	Python	temp22	1
3041	3043	12	select * from Telecom.dbo.telecom_users	Python	temp22	1
3042	3044	12	insert into Telecom.dbo.telecom_users values (...	Python	temp22	1
3043	3045	12	use Weather select top 1000 * from weather whe...	Python	temp22	1
3044	3046	12	use Telecom select top 1000 * from telecom_use...	Python	temp22	1

3045 rows × 26 columns

Calculating frequency of queries and categorizing a row containing hot or not (cold data) depending on the threshold frequency calculated below:

In [7]:

```
dataCopy['Frequency']=dataCopy['TextData'].replace(dataCopy['TextData'].value_co
dataCopy['HotData'] = 'n'
dataCopy
```

Out[7]:

	RowNumber	EventClass	TextData	ApplicationName	LoginName	ClientPrc
0	2	12	select * from Weather.dbo.weather	Python	temp	
1	3	12	select * from Telecom.dbo.telecom_users	Python	temp	
2	4	12	insert into Telecom.dbo.telecom_users values (...	Python	temp	
3	5	12	select * from Telecom.dbo.telecom_users	Python	temp	

	RowNumber	EventClass	TextData	ApplicationName	LoginName	ClientPrc
4	6	12	insert into Weather.dbo.weather values (42.45,...	Python	temp	
...	...	...	...	...	...	
3040	3042	12	select * from Weather.dbo.weather	Python	temp22	1
3041	3043	12	select * from Telecom.dbo.telecom_users	Python	temp22	1
3042	3044	12	insert into Telecom.dbo.telecom_users values (...	Python	temp22	1
3043	3045	12	use Weather select top 1000 * from weather whe...	Python	temp22	1
3044	3046	12	use Telecom select top 1000 * from telecom_use...	Python	temp22	1

3045 rows × 28 columns

In [8]:
```
threshold = dataCopy['Frequency'].mean()
threshold
```

Out[8]: 110.18357963875205

In [9]:
```
dataCopy['HotData'].mask(dataCopy['Frequency'] > threshold, 'y', inplace=True)
dataCopy
```

Out[9]:

	RowNumber	EventClass	TextData	ApplicationName	LoginName	ClientPrc
0	2	12	select * from Weather.dbo.weather	Python	temp	
1	3	12	select * from Telecom.dbo.telecom_users	Python	temp	
2	4	12	insert into Telecom.dbo.telecom_users values (...	Python	temp	
3	5	12	select * from Telecom.dbo.telecom_users	Python	temp	
4	6	12	insert into Weather.dbo.weather values (42.45,...	Python	temp	
...	...	...	...	...	...	
3040	3042	12	select * from Weather.dbo.weather	Python	temp22	1
3041	3043	12	select * from Telecom.dbo.telecom_users	Python	temp22	1

	RowNumber	EventClass	TextData	ApplicationName	LoginName	ClientPrc
3042	3044	12	insert into Telecom.dbo.telecom_users values (...	Python	temp22	1
3043	3045	12	use Weather select top 1000 * from weather whe...	Python	temp22	1
3044	3046	12	use Telecom select top 1000 * from telecom_use...	Python	temp22	1

3045 rows × 28 columns

In [10]:
```
pd.crosstab(dataCopy['HotData'],dataCopy['Frequency'])
```

Out[10]:

Frequency	1	2	4	5	6	7	9	10	11	12	...	68	135	152	164	171	172	173	179	1
HotData																				
n	15	6	52	110	78	7	9	50	44	72	...	68	0	0	0	0	0	0	0	
y	0	0	0	0	0	0	0	0	0	0	...	0	135	152	164	171	172	346	179	1

2 rows × 35 columns

Need special case to handle non-numerical data

In [11]:
```
dataCopy.dtypes
```

Out[11]:
```
RowNumber             int64
EventClass            int64
TextData             object
ApplicationName      object
LoginName            object
ClientProcessID     float64
SPID                float64
StartTime            object
CPU                 float64
Reads               float64
Writes              float64
Duration            float64
EndTime              object
DatabaseID          float64
DatabaseName         object
Error               float64
EventSequence       float64
GroupID             float64
HostName             object
LoginSid             object
RequestID           float64
RowCounts           float64
ServerName           object
SessionLoginName     object
TransactionID       float64
XactSequence        float64
Frequency             int64
```

```
HotData              object
dtype: object
```

Removing features with no unique values as they render to be irrelevant

In [14]:
```
dataCopy.nunique(axis=0)
```

Out[14]:
```
RowNumber           3045
EventClass             1
TextData             114
ApplicationName        6
LoginName             25
ClientProcessID        7
SPID                  23
StartTime           2235
CPU                   20
Reads                197
Writes                14
Duration            2445
EndTime             1980
DatabaseID             7
DatabaseName           7
Error                  2
EventSequence       3045
GroupID                1
HostName               1
LoginSid              25
RequestID              1
RowCounts            129
ServerName             1
SessionLoginName      25
TransactionID         21
XactSequence          13
Frequency             35
HotData                2
dtype: int64
```

In [15]:
```
for col in dataCopy.columns:
    if len(dataCopy[col].unique()) == 1:
        dataCopy.drop(col,inplace=True,axis=1)
dataCopy.columns
```

Out[15]:
```
Index(['RowNumber', 'TextData', 'ApplicationName', 'LoginName',
       'ClientProcessID', 'SPID', 'StartTime', 'CPU', 'Reads', 'Writes',
       'Duration', 'EndTime', 'DatabaseID', 'DatabaseName', 'Error',
       'EventSequence', 'LoginSid', 'RowCounts', 'SessionLoginName',
       'TransactionID', 'XactSequence', 'Frequency', 'HotData'],
      dtype='object')
```

Data Analysis

As shown there are 114 unique queries in the trace generation data

In [13]:
```
dataCopy.TextData.nunique()
```

Out[13]:
```
114
```

Gives most metrics for the data

In [12]:
```
dataCopy.describe()
```

Out[12]:

	RowNumber	EventClass	ClientProcessID	SPID	CPU	Reads	
count	3045.000000	3045.0	3045.000000	3045.000000	3045.000000	3045.000000	3045
mean	1524.000000	12.0	7447.224959	59.055501	6.640394	154.346798	
std	879.160111	0.0	5767.673558	5.765330	78.623275	637.640198	
min	2.000000	12.0	0.000000	51.000000	0.000000	0.000000	0
25%	763.000000	12.0	0.000000	53.000000	0.000000	6.000000	0
50%	1524.000000	12.0	9372.000000	59.000000	0.000000	35.000000	0
75%	2285.000000	12.0	12580.000000	63.000000	0.000000	114.000000	0
max	3046.000000	12.0	18080.000000	75.000000	3046.000000	30142.000000	23

In [16]:
```
pd.crosstab([dataCopy['DatabaseID'],dataCopy['DatabaseName']],dataCopy['Frequenc
```

Out[16]:

Frequency		1	2	4	5	6	7	9	10	11	12	...	68	135	152	164	171	17
DatabaseID	**DatabaseName**																	
1.0	**master**	6	4	4	30	57	7	9	31	11	60	...	3	8	8	0	0	
4.0	**msdb**	0	0	0	0	0	0	0	0	0	12	...	0	0	0	0	0	
5.0	**CabRides**	3	0	12	10	5	0	0	2	11	0	...	15	29	33	164	0	4
6.0	**Students**	1	0	12	14	5	0	0	1	11	0	...	15	39	39	0	0	5
7.0	**Telecom**	2	0	12	15	0	0	0	1	11	0	...	21	27	33	0	0	3
8.0	**Weather**	3	2	12	26	6	0	0	5	0	0	...	14	32	39	0	171	3
9.0	**Trace**	0	0	0	15	5	0	0	10	0	0	...	0	0	0	0	0	

7 rows × 35 columns

In [17]:
```
pd.crosstab([dataCopy['Reads']],dataCopy['Frequency'])
```

Out[17]:

Frequency	1	2	4	5	6	7	9	10	11	12	...	68	135	152	164	171	172	173	179	18
Reads																				
0.0	1	0	8	61	60	7	9	30	34	34	...	0	0	0	0	0	0	0	0	
1.0	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	40	0	43	
2.0	0	0	0	0	0	0	0	0	0	16	...	0	0	0	0	0	2	0	6	
3.0	0	0	0	0	0	0	0	1	0	0	...	0	0	0	0	0	0	0	0	
4.0	0	0	0	0	0	0	0	5	0	0	...	0	0	0	0	0	1	0	2	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1861.0	0	0	0	0	0	0	0	0	0	0	...	0	2	0	0	0	0	0	0	

Frequency	1	2	4	5	6	7	9	10	11	12	...	68	135	152	164	171	172	173	179	18
Reads																				
1916.0	0	0	1	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	
2317.0	1	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	
2490.0	0	2	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	
30142.0	1	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	

197 rows × 35 columns

Engineering Categorical Features

In [18]:

```
dataCopy = pd.get_dummies(dataCopy, columns=['TextData'], prefix = 'Query')
dataCopy = pd.get_dummies(dataCopy, columns=['ApplicationName'], prefix = 'Appli
dataCopy = pd.get_dummies(dataCopy, columns=['LoginName'], prefix = 'LoginName')
dataCopy = pd.get_dummies(dataCopy, columns=['DatabaseName'], prefix = 'Database

dataCopy
```

Out[18]:

RowNumber	ClientProcessID	SPID	StartTime	CPU	Reads	Writes	Duration	EndTime
0	2	9372.0	58.0	51:58.6	0.0	99.0	0.0	2336357.0	52:00.9
1	3	9372.0	58.0	52:00.9	0.0	127.0	0.0	2339646.0	52:03.2
2	4	9372.0	58.0	52:03.2	0.0	63.0	0.0	8470.0	52:03.2
3	5	9372.0	58.0	52:05.2	0.0	6.0	0.0	2020313.0	52:07.3
4	6	9372.0	58.0	52:07.3	0.0	100.0	1.0	4249.0	52:07.3
...	...	...	...	...	...	...	...	...	...
3040	3042	18080.0	71.0	00:57.7	0.0	20.0	0.0	2011701.0	00:59.7
3041	3043	18080.0	71.0	00:59.7	0.0	21.0	0.0	2009220.0	01:01.8
3042	3044	18080.0	71.0	01:01.8	0.0	63.0	0.0	2479.0	01:01.8
3043	3045	18080.0	71.0	01:03.8	0.0	54.0	0.0	2015868.0	01:05.8
3044	3046	18080.0	71.0	01:05.8	0.0	32.0	0.0	1868027.0	01:07.6

3045 rows × 171 columns

Prediction Model - Decision Tree Classifier

In this section, we apply a decision tree classifier to predict the frequency of queries that would be prefetched in a cache and identify hot data.

Extract target class from features and remove irrelevant features

In [19]:
```
Y = dataCopy['HotData']
X = dataCopy.drop(['RowNumber','StartTime','EndTime','DatabaseID','SessionLoginN
```

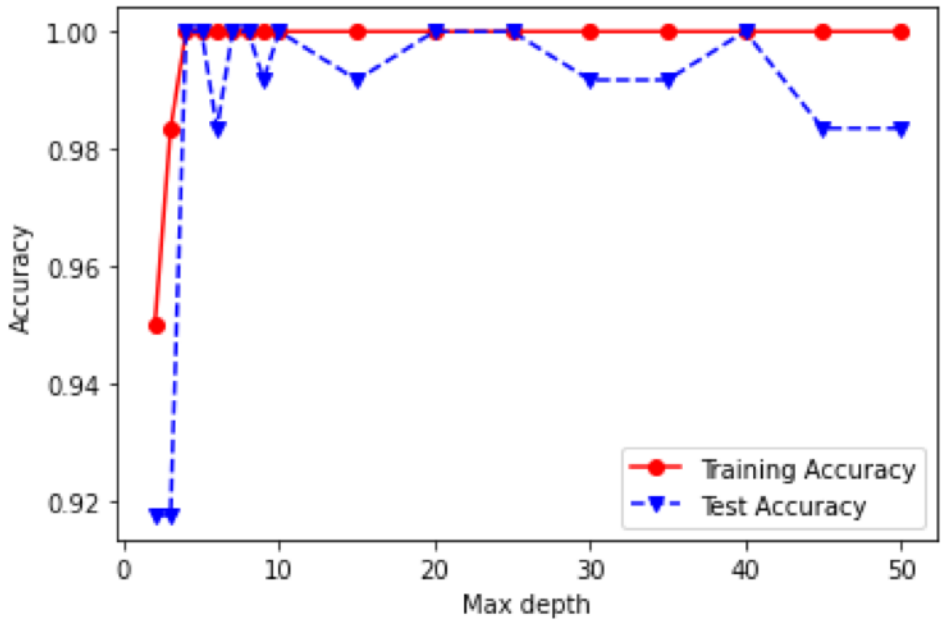
Training and Test set creation

In [21]:
```
from sklearn.model_selection import train_test_split
X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.8, random_
```

Model fitting and evaluation

In [22]:
```
from sklearn import tree
from sklearn.metrics import accuracy_score
import matplotlib.pyplot as plt
from numpy.random import random

%matplotlib inline

maxdepths = [2,3,4,5,6,7,8,9,10,15,20,25,30,35,40,45,50]

trainAcc = np.zeros(len(maxdepths))
testAcc = np.zeros(len(maxdepths))

index = 0
for depth in maxdepths:
    clf = tree.DecisionTreeClassifier(criterion='entropy',max_depth=depth)
    clf = clf.fit(X_train, Y_train)
    Y_predTrain = clf.predict(X_train)
    Y_predTest = clf.predict(X_test)
    trainAcc[index] = accuracy_score(Y_train, Y_predTrain)
    testAcc[index] = accuracy_score(Y_test, Y_predTest)
    index += 1

########################################
# Plot of training and test accuracies
########################################

plt.plot(maxdepths,trainAcc,'ro-',maxdepths,testAcc,'bv--')
plt.legend(['Training Accuracy','Test Accuracy'])
plt.xlabel('Max depth')
plt.ylabel('Accuracy')
```

Out[22]:
```
Text(0, 0.5, 'Accuracy')
```



Build the decision tree classifier and train data

As observed there is a 99% accuracy for predictions

In [23]:

```
clf = tree.DecisionTreeClassifier(criterion='entropy',max_depth=25)
clf = clf.fit(X_train, Y_train)
Y_predTrain = clf.predict(X_train)
Y_predTest = clf.predict(X_test)
trainAcc = accuracy_score(Y_train, Y_predTrain)
testAcc = accuracy_score(Y_test, Y_predTest)
print(trainAcc,testAcc)
```

```
1.0 0.9991789819376026
```

Predictions

In [24]:

```
Y_test_copy = Y_test.reset_index(drop=True)
predictions = pd.concat([Y_test_copy,pd.Series(Y_predTest,name='Predicted Class'
predictions
```

Out[24]:

	HotData	Predicted Class
0	n	n
1	y	y
2	y	y
3	y	y
4	n	n
...	...	...
2431	n	n
2432	n	n

	HotData	Predicted Class
2433	y	y
2434	y	y
2435	y	y

2436 rows × 2 columns

Extracting frequent queries from the predictions

In [25]:
```
X_test_copy = X_test.reset_index(drop=True)
result_with_frequency_predictions = pd.concat([X_test_copy,pd.Series(Y_predTest,
result_with_frequency_predictions
```

Out[25]:

	ClientProcessID	SPID	CPU	Reads	Writes	Duration	Error	EventSequence	RowCounts
0	9372.0	58.0	0.0	23.0	0.0	20190.0	0.0	1975.0	1.0
1	0.0	59.0	15.0	173.0	0.0	15359.0	0.0	3378.0	6299.0
2	0.0	59.0	0.0	36.0	0.0	1050.0	0.0	3305.0	1086.0
3	18080.0	70.0	0.0	53.0	0.0	2008416.0	2.0	5782.0	0.0
4	12580.0	55.0	0.0	0.0	0.0	94.0	0.0	5062.0	0.0
...	...	...	...	...	...	...	...	...	...
2431	12580.0	55.0	16.0	401.0	0.0	15833.0	0.0	5271.0	1.0
2432	12580.0	53.0	0.0	0.0	0.0	102.0	0.0	4262.0	0.0
2433	9372.0	58.0	0.0	53.0	0.0	2015076.0	2.0	2035.0	0.0
2434	0.0	59.0	0.0	114.0	0.0	1397.0	0.0	3030.0	1.0
2435	0.0	59.0	0.0	1.0	0.0	2223.0	0.0	3714.0	1.0

2436 rows × 163 columns

In [26]:
```
rows_with_predicted_hot_data = result_with_frequency_predictions.loc[result_with

query_columns = rows_with_predicted_hot_data.filter(like='Query_').columns
rows_with_predicted_hot_data = rows_with_predicted_hot_data[query_columns]
```

In [27]:
```
for col in rows_with_predicted_hot_data.columns:
    if (rows_with_predicted_hot_data[col] == 0).all() == True:
        rows_with_predicted_hot_data.drop(col,inplace=True,axis=1)
print(len(rows_with_predicted_hot_data.columns),rows_with_predicted_hot_data.col
```

```
e InternetService='DSL';      use Weather select top 1000 * from weather where l
ocation='Fenway';      insert into CabRides.dbo.cab_rides values (0.44, 'Lyft',
1540000000000, 'North Station', 'Haymarket Square', 16.5, 1, 'e8bac1d1-6e83-4ebd
-a0a9-bfcf9de1a86f', 'lyft_line', 'UberX');      insert into Students.dbo.Studen
tsPerformance values ('female', 'group B', 'bachelors degree', 'standard', 'comp
leted', 72, 80, 94);      insert into Telecom.dbo.telecom_users values (6780, '7
```

```
010-BRBUU', 'Male', 0, 'Yes', 'No', 75, 'Yes', 'No', 'DSL', 'Yes', 'No', 'No',
'Yes', 'No', 'No', 'Two Year', 'Yes', 'Credit card', 24.2, 3370.2, 'No');      i
nsert into Weather.dbo.weather values (42.45, 'Fenway', 1, 1012.17, 0.1089, defa
ult, 0.96, 1.53);      delete top (1) from CabRides.dbo.cab_rides where name='Ly
ft';      delete top (1) from Students.dbo.StudentsPerformance where gender='mal
e';      delete top (1) from Telecom.dbo.telecom_users where InternetService='DS
L';      delete top (1) from Weather.dbo.weather where location='Fenway';   SET
@cnt = @cnt + 1;  END;',
       'Query_insert into CabRides.dbo.cab_rides values (0.44, 'Lyft', 154000000
0000, 'North Station', 'Haymarket Square', 16.5, 1, 'e8bac1d1-6e83-4ebd-a0a9-bfc
f9de1a86f', 'lyft_line', 'UberX')',
       'Query_insert into Students.dbo.StudentsPerformance values ('female', 'gr
oup B', 'bachelors degree', 'standard', 'completed', 72, 80, 94)',
       'Query_select * from CabRides.dbo.cab_rides',
       'Query_select * from Students.dbo.StudentsPerformance',
       'Query_select * from Telecom.dbo.telecom_users',
       'Query_select * from Weather.dbo.weather',
       'Query_use CabRides select top 1000 * from cab_rides where name='Lyft'',
       'Query_use Students select top 1000 * from StudentsPerformance where gend
er='male'',
       'Query_use Telecom select top 1000 * from telecom_users where InternetSer
vice='DSL'',
       'Query_use Weather select top 1000 * from weather where location='Fenwa
y''],
      dtype='object')
```

Writing the frequent queries with hot data to output file

In [28]:

```
queries_with_hot_data_file = open('frequent_queries.txt','w')
i = 1
for item in rows_with_predicted_hot_data.columns:
    queries_with_hot_data_file.write('Frequent Query '+str(i)+': '+ str(item)[6:
    i += 1

queries_with_hot_data_file.write('_____ \n')

queries_with_hot_data_file.close()
```

Visualization of the Decision Tree Classifier

In [29]:

```
uniqueFrequencies = Y.unique()
classLabels = []

for value in uniqueFrequencies:
    classLabels.append(str(value))
classLabels
```

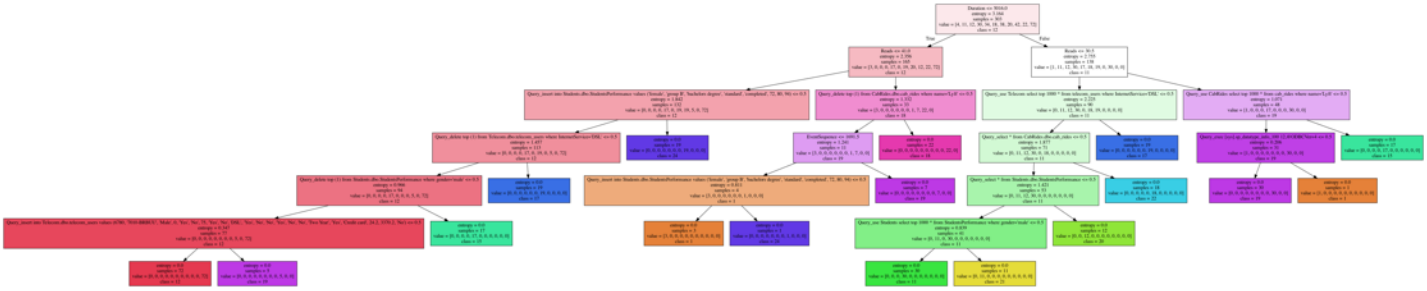
Out[29]:

```
['y', 'n']
```

In [30]:

```
import pydotplus
from IPython.display import Image

dot_data = tree.export_graphviz(clf, feature_names=X_test.columns, class_names=c
                                out_file=None)
graph = pydotplus.graph_from_dot_data(dot_data)
Image(graph.create_png())
```

Out[30]:



In [ ]: