Packages ¶

In [131]:

```
# Base
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

# Feature selection
from sklearn.ensemble import ExtraTreesClassifier

# Balanced set creation
from imblearn.over_sampling import SMOTE

# Logistic regression
from sklearn import linear_model

# Metrics
from sklearn.metrics import accuracy_score, auc, classification_report, confusio
n_matrix, roc_curve
```

Get data

In [132]:

```
# Read CSV
path = 'telco.csv'
df = pd.read_csv(path)

# Check import
df.head()
```

Out[132]:

	customerID	gender	SeniorCitizen	Partner	Dependents	tenure	PhoneService	Mu
0	7590-VHVEG	Female	0	Yes	No	1	No	No se
1	5575-GNVDE	Male	0	No	No	34	Yes	No
2	3668-QPYBK	Male	0	No	No	2	Yes	No
3	7795-CFOCW	Male	0	No	No	45	No	No se
4	9237-HQITU	Female	0	No	No	2	Yes	No

5 rows × 21 columns

Drop customer ID

We cannot use that as a feature.

In [133]:

```
# Drop columns
df.drop('customerID', axis = 1, inplace = True)
```

Change data types

In [134]:

```
# Check types
print(df.dtypes)
```

```
gender               object
SeniorCitizen         int64
Partner              object
Dependents           object
tenure                int64
PhoneService         object
MultipleLines        object
InternetService      object
OnlineSecurity       object
OnlineBackup         object
DeviceProtection     object
TechSupport          object
StreamingTV          object
StreamingMovies      object
Contract             object
PaperlessBilling     object
PaymentMethod        object
MonthlyCharges      float64
TotalCharges         object
Churn                object
dtype: object
```

In [135]:

```
# Change type of total charges to float
df['TotalCharges'] = pd.to_numeric(df['TotalCharges'], errors='coerce')
print(df.dtypes)
```

```
gender               object
SeniorCitizen         int64
Partner              object
Dependents           object
tenure                int64
PhoneService         object
MultipleLines        object
InternetService      object
OnlineSecurity       object
OnlineBackup         object
DeviceProtection     object
TechSupport          object
StreamingTV          object
StreamingMovies      object
Contract             object
PaperlessBilling     object
PaymentMethod        object
MonthlyCharges      float64
TotalCharges        float64
Churn                object
dtype: object
```

Handle missing values

In [136]:

```
# Count number of missing values
print(df.shape[0] - df.count())
```

```
gender              0
SeniorCitizen       0
Partner             0
Dependents          0
tenure              0
PhoneService        0
MultipleLines       0
InternetService     0
OnlineSecurity      0
OnlineBackup        0
DeviceProtection    0
TechSupport         0
StreamingTV         0
StreamingMovies     0
Contract            0
PaperlessBilling    0
PaymentMethod       0
MonthlyCharges      0
TotalCharges       11
Churn               0
dtype: int64
```

In [137]:

```
# Replace missing values for feature 'TotalCharges'
df['TotalCharges'].fillna(0.0, inplace = True)
```

Explore data

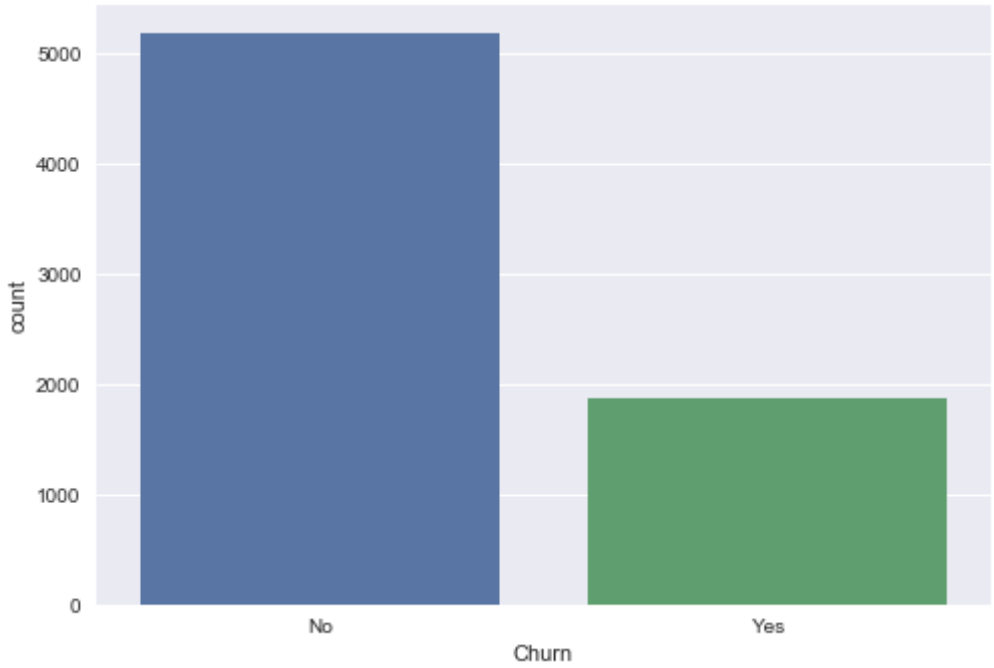
In [138]:

```
# Check shape
print(df.shape)
```

```
(7043, 20)
```

In [139]:

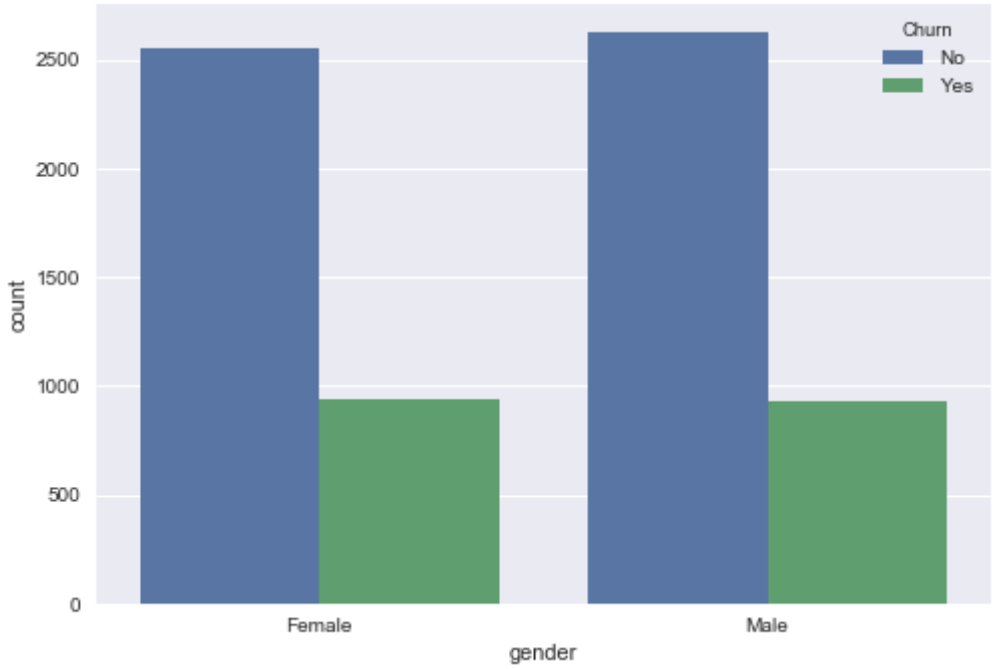
```
# Check number of clients that have left
sns.countplot(df['Churn'])
plt.show()
print(df.groupby('Churn').size())
```

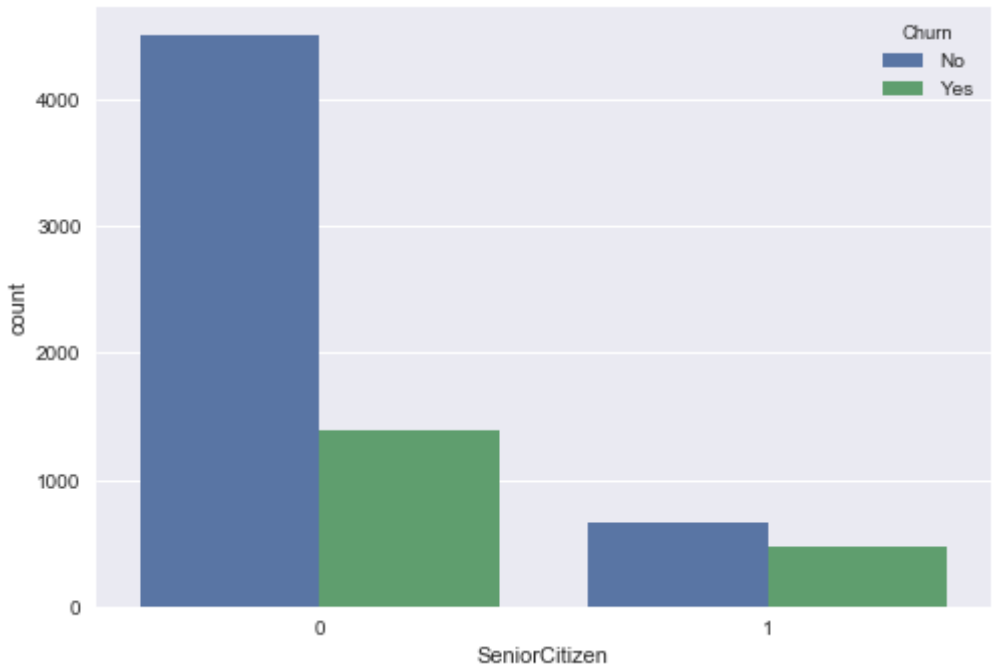


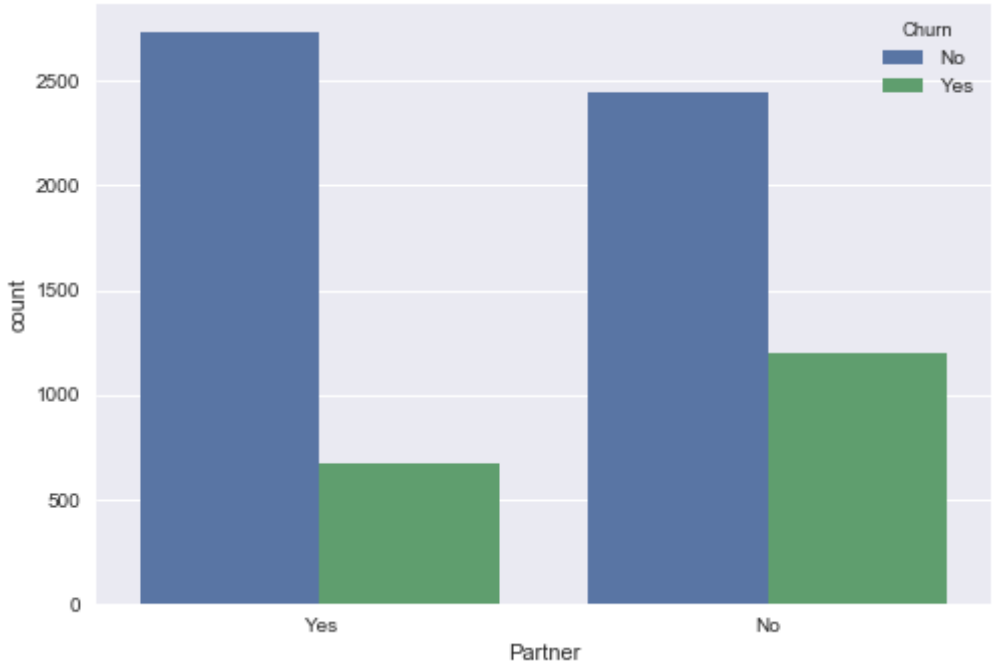

```
Churn
No     5174
Yes    1869
dtype: int64
```

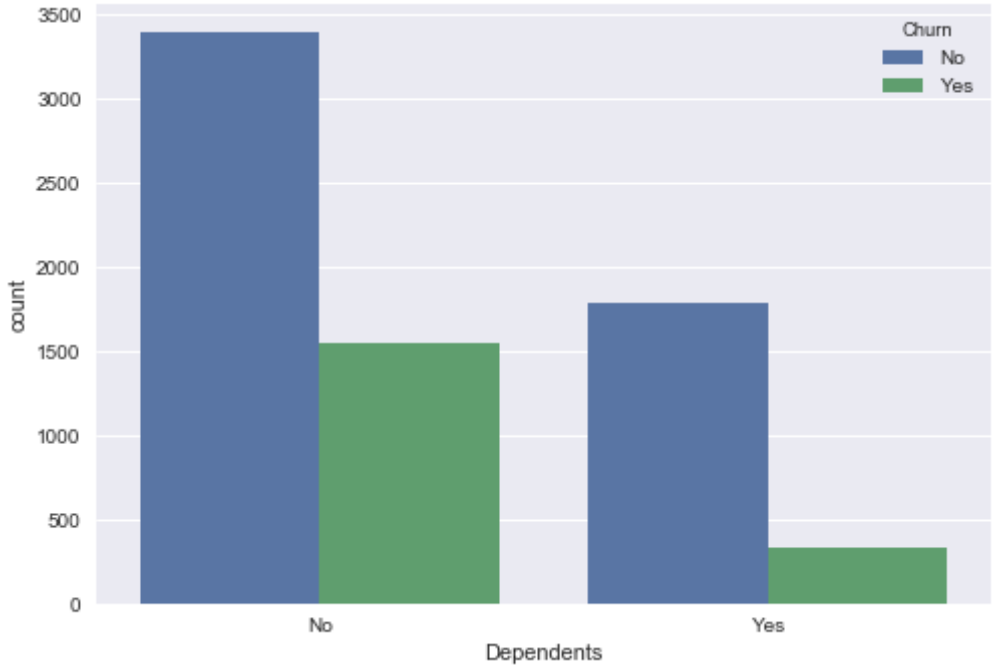
In [140]:

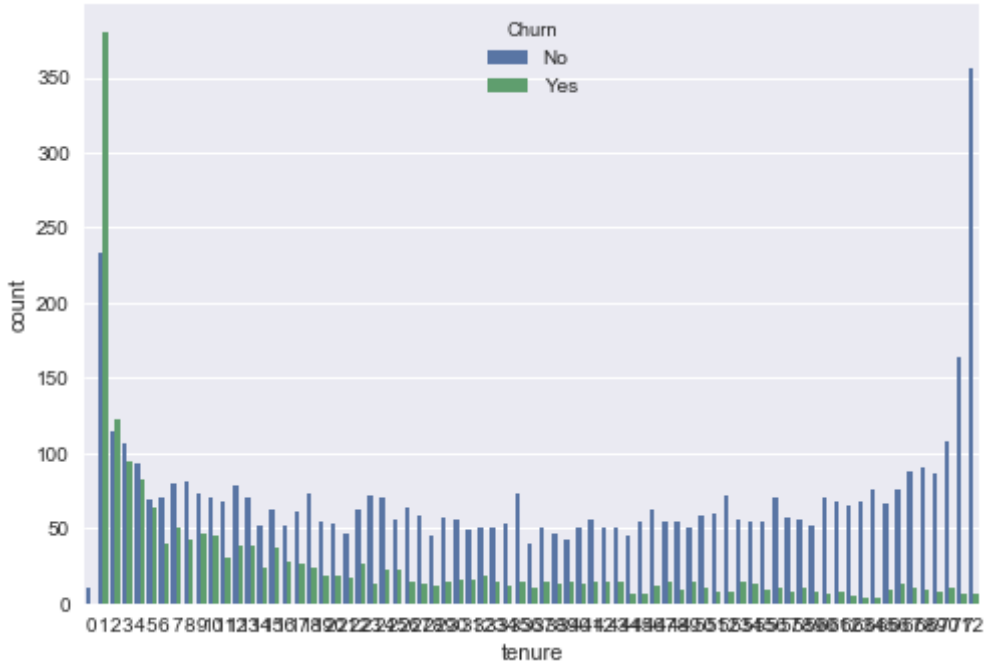
```
# Plot all distributions
for c in df.columns:
    if c == 'Churn':
        continue
    elif (df[c].dtype == np.object) or (df[c].dtype == np.int64):
        sns.countplot(x = c, hue = 'Churn', data = df)
        plt.show()
    else:
        f,a = plt.subplots(1, 2)
        sns.distplot(df[df['Churn'] == 'No'][c], kde = False, rug = False, ax =
a[0])
        a[0].set_title('No')
        sns.distplot(df[df['Churn'] == 'Yes'][c], kde = False, rug = False, ax =
 a[1], color = 'g')
        a[1].set_title('Yes')
        plt.show()
```

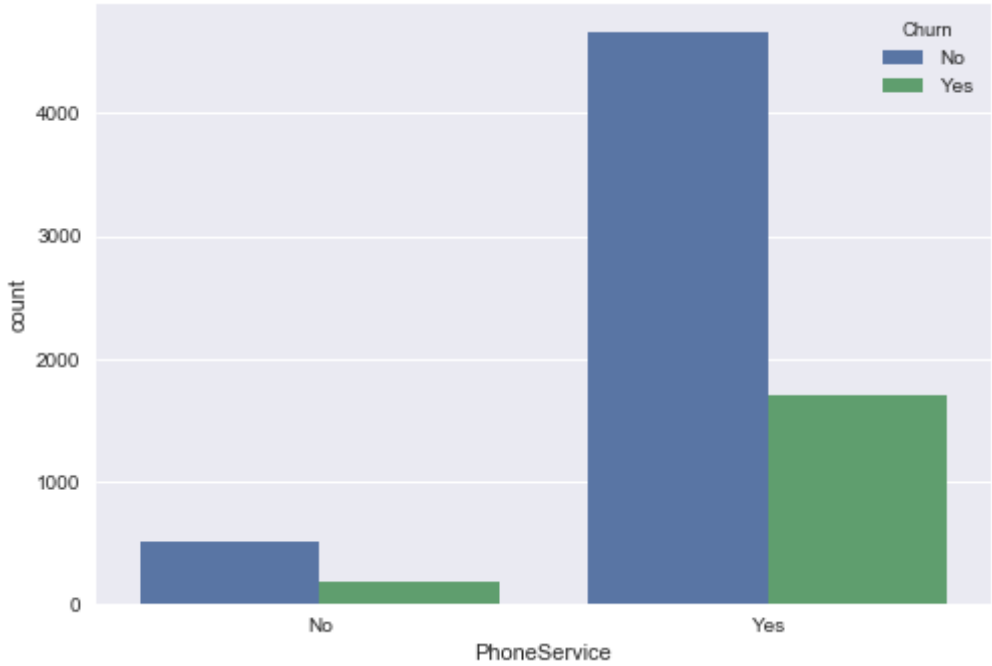

Churn
No
Yes
2500
2000
1500
1000
500
0
count
Female
Male
gender

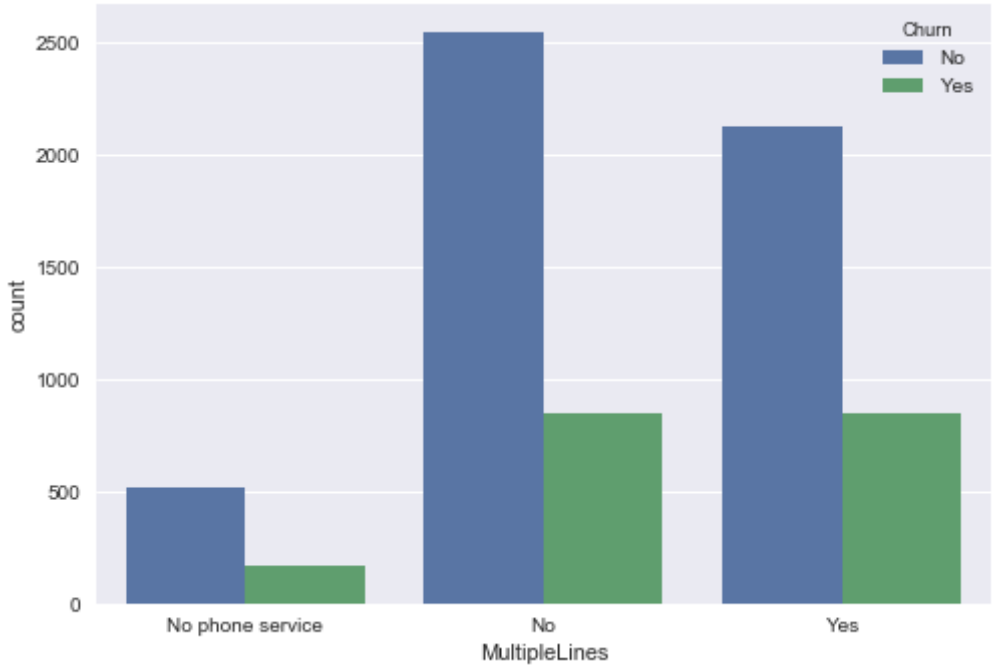

Churn
No
Yes
4000
3000
2000
1000
0
count
0
1
SeniorCitizen

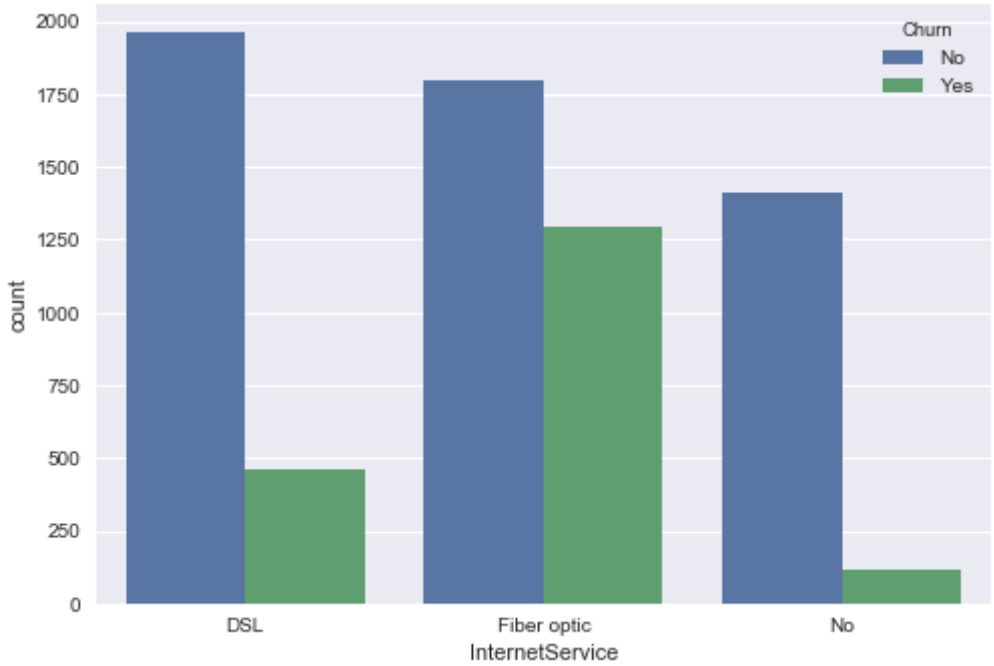

Churn
No
Yes
2500
2000
1500
1000
500
0
count
Yes
No
Partner

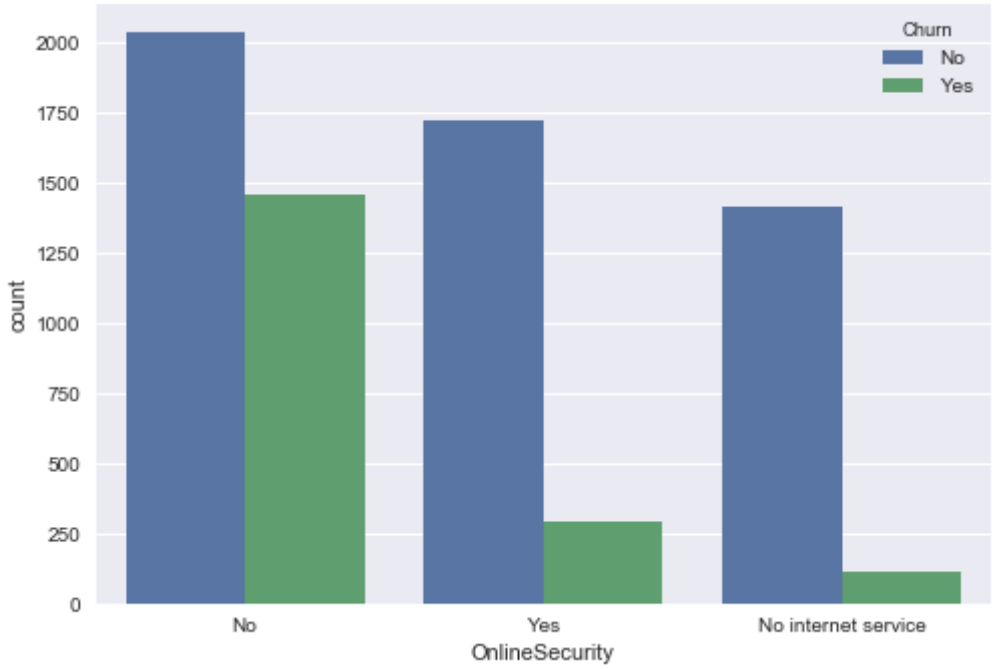

Churn
No
Yes
3500
3000
2500
2000
1500
1000
500
0
count
No
Yes
Dependents

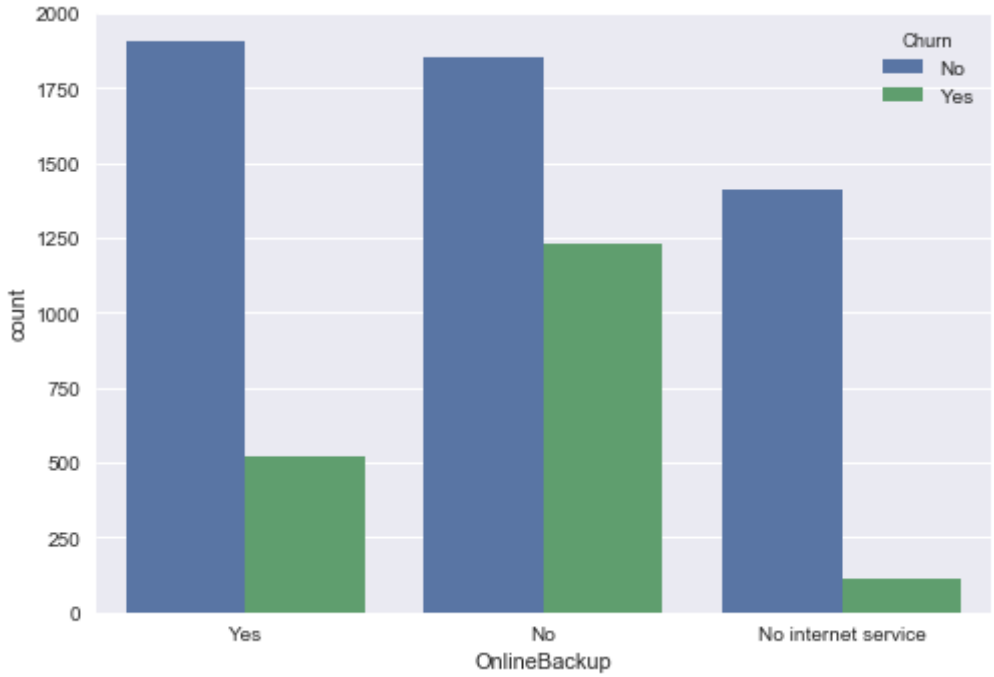

Churn
No
Yes
count
tenure

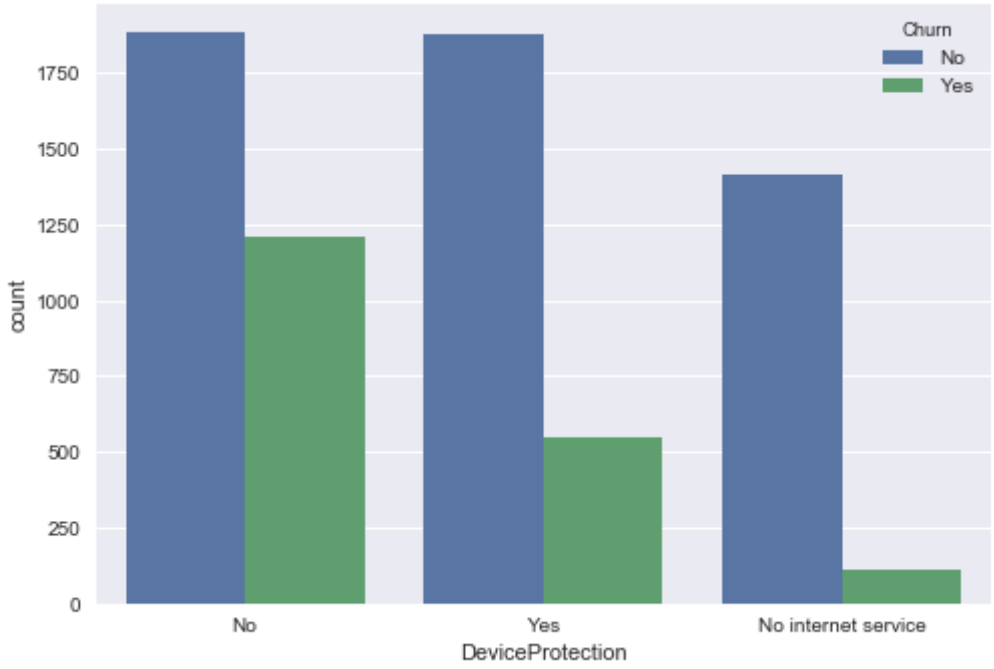

Churn
No
Yes
count
PhoneService

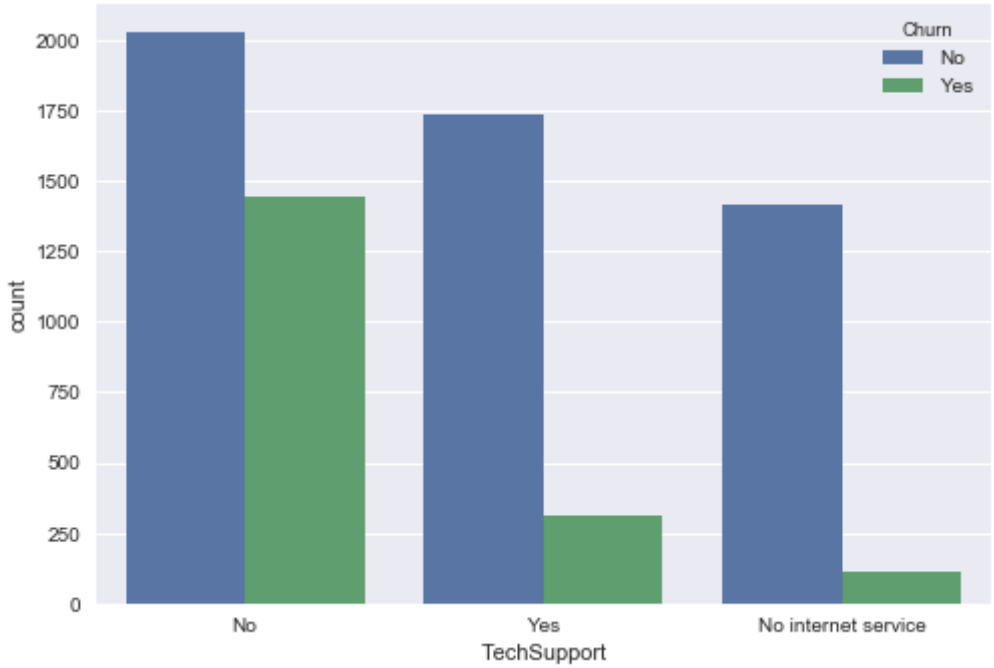

Churn
No
Yes
2500
2000
1500
1000
500
0
count
No phone service
No
Yes
MultipleLines

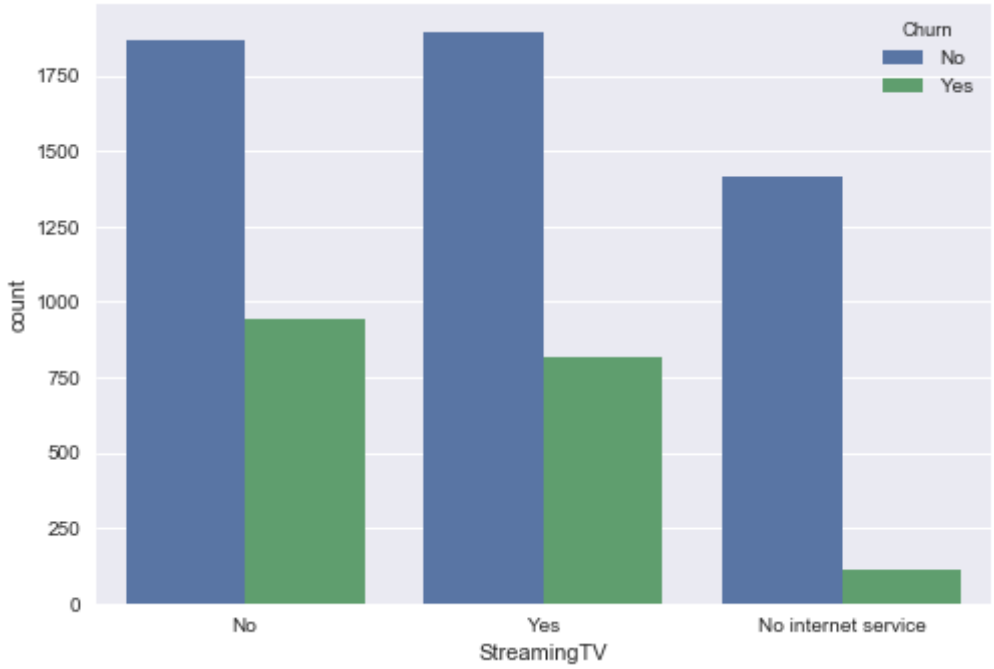

Churn
No
Yes
2000
1750
1500
1250
1000
750
500
250
0
count
DSL
Fiber optic
No
InternetService

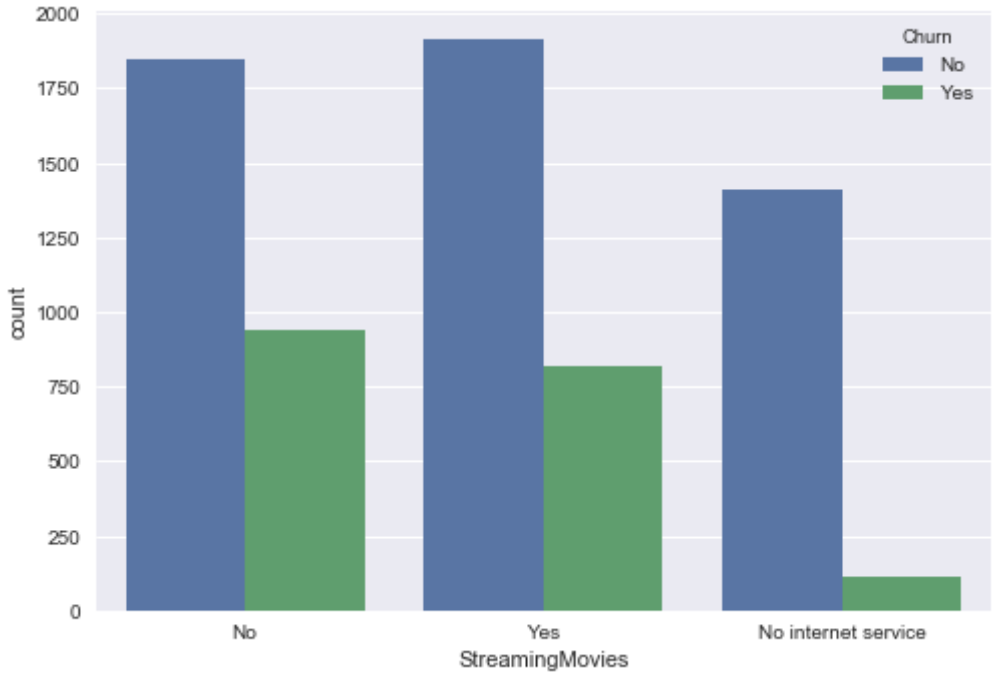

Churn
No
Yes
2000
1750
1500
1250
1000
750
500
250
0
count
No
Yes
No internet service
OnlineSecurity

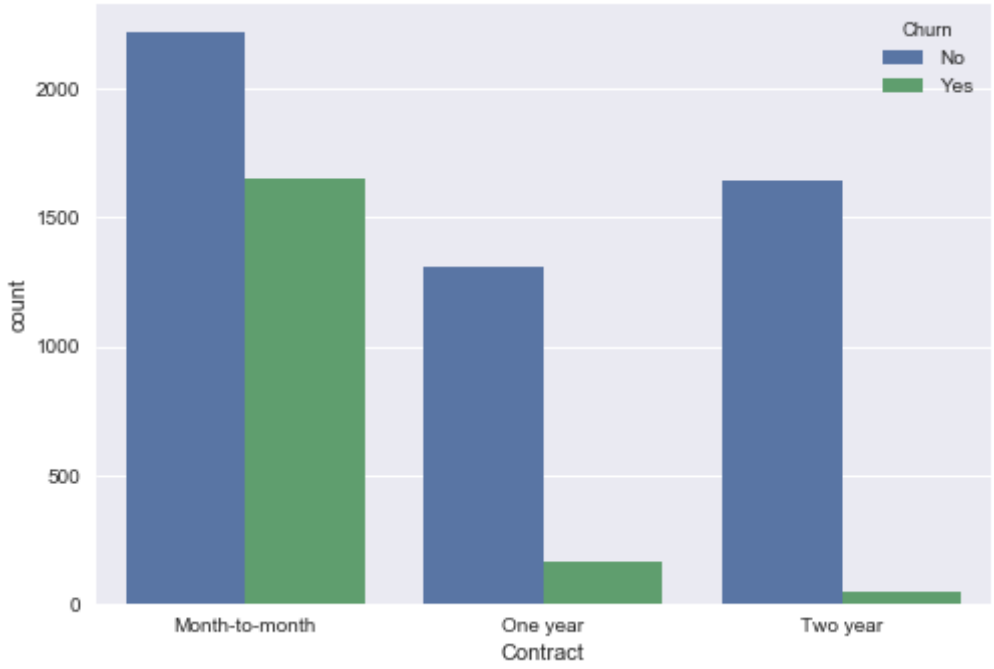

Churn
No
Yes
2000
1750
1500
1250
1000
750
500
250
0
count
Yes
No
No internet service
OnlineBackup

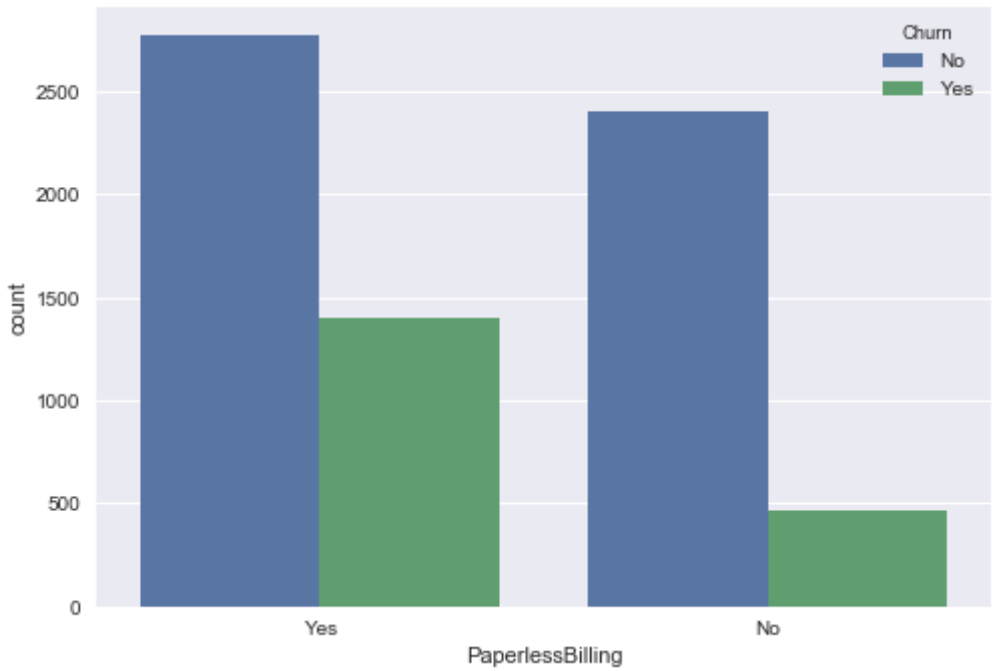

Churn
No
Yes
1750
1500
1250
1000
750
500
250
0
count
No
Yes
No internet service
DeviceProtection

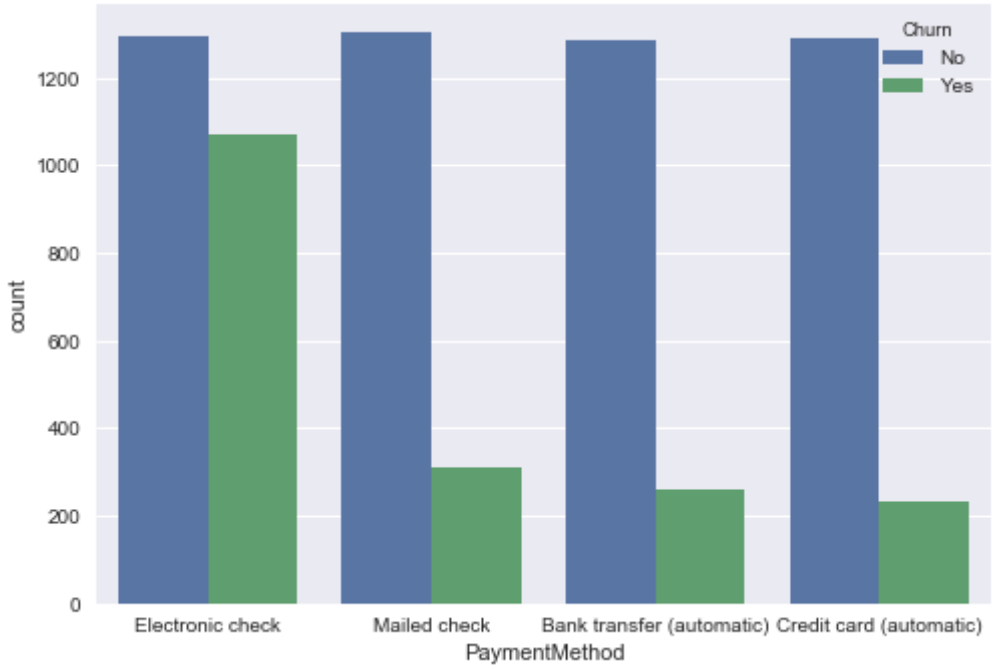

Churn
No
Yes
2000
1750
1500
1250
1000
750
500
250
0
count
No
Yes
No internet service
TechSupport

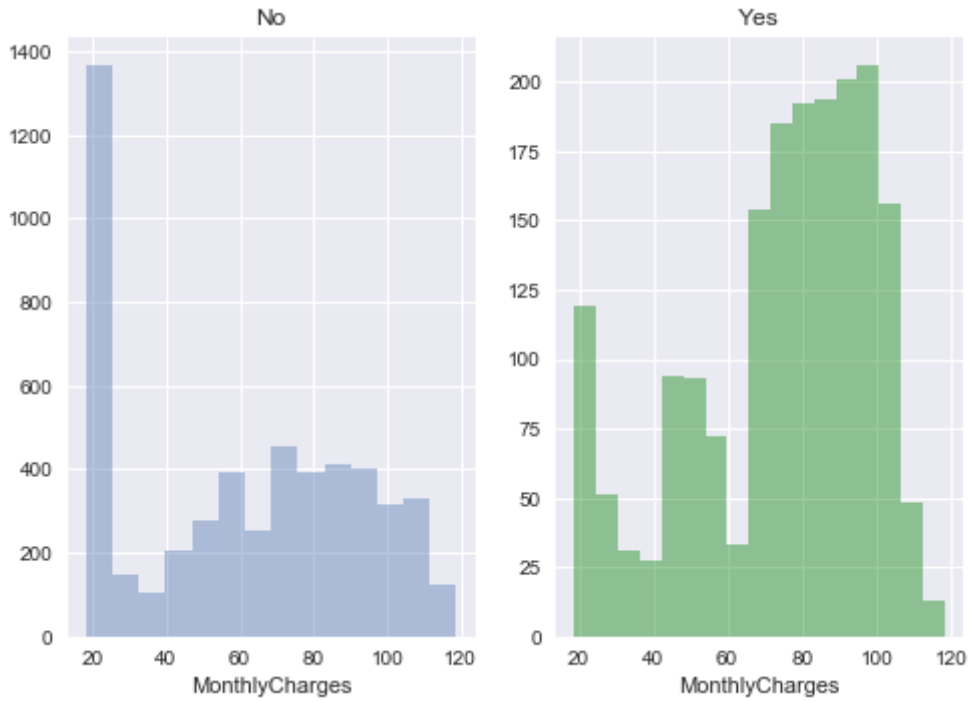

Churn
No
Yes
1750
1500
1250
1000
750
500
250
0
count
No
Yes
No internet service
StreamingTV

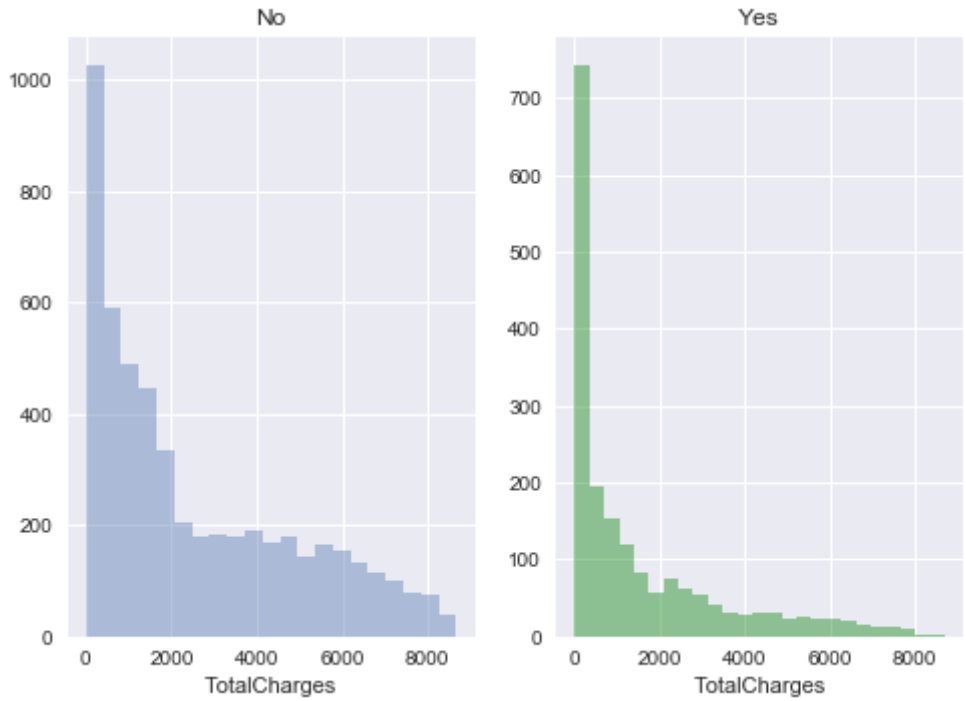

2000
Churn
No
Yes
1750
1500
1250
1000
750
500
250
0
count
No
Yes
No internet service
StreamingMovies


Churn
No
Yes
2000
1500
1000
500
0
count
Month-to-month
One year
Two year
Contract


Churn
No
Yes
2500
2000
1500
1000
500
0
count
Yes
No
PaperlessBilling


Churn
No
Yes
count
0
200
400
600
800
1000
1200
Electronic check
Mailed check
Bank transfer (automatic)
Credit card (automatic)
PaymentMethod


No
Yes
0
200
400
600
800
1000
1200
1400
0
25
50
75
100
125
150
175
200
20
40
60
80
100
120
MonthlyCharges
MonthlyCharges



Transform categorical features into one feature by category

Map binary variables to 0/1. I could also use 'astype('category')' and 'pd.get_dummies' but we would then need to remove each time a column (since when k categories, we keep only k-1 features).

In [141]:

```
# Target
df['Churn'] = df['Churn'].map(lambda x: 1 if x == 'Yes' else 0)

# Features
df['gender'] = df['gender'].map(lambda x: 1 if x == 'Male' else 0)
df['Partner'] = df['Partner'].map(lambda x: 1 if x == 'Yes' else 0)
df['PhoneService'] = df['PhoneService'].map(lambda x: 1 if x == 'Yes' else 0)
df['PaperlessBilling'] = df['PaperlessBilling'].map(lambda x: 1 if x == 'Yes' el
se 0)
df['Dependents'] = df['Dependents'].map(lambda x: 1 if x == 'Yes' else 0)
```

Create 1 feature for each category.

In [142]:

```
# Set type 'category'
df['OnlineSecurity'] = df['OnlineSecurity'].astype('category')
df['OnlineBackup'] = df['OnlineBackup'].astype('category')
df['DeviceProtection'] = df['DeviceProtection'].astype('category')
df['TechSupport'] = df['TechSupport'].astype('category')
df['StreamingTV'] = df['StreamingTV'].astype('category')
df['StreamingMovies'] = df['StreamingMovies'].astype('category')
df['MultipleLines'] = df['MultipleLines'].astype('category')
df['InternetService'] = df['InternetService'].astype('category')
df['Contract'] = df['Contract'].astype('category')
df['PaymentMethod'] = df['PaymentMethod'].astype('category')

# Select categorical features
for c in df.select_dtypes(include=['category']):
    print(c)

# Do categorical encoding, removing automatically one of the categories
# COMMENT: I did not do that so that I could choose which category to drop
# df = pd.get_dummies(df, drop_first = True)

# Do categorical encoding without dropping one of the categories
df = pd.get_dummies(df, drop_first = False)
```

```
MultipleLines
InternetService
OnlineSecurity
OnlineBackup
DeviceProtection
TechSupport
StreamingTV
StreamingMovies
Contract
PaymentMethod
```

In [143]:

```
# Check existing columns in data frame
print(df.dtypes)
```

```
gender                                     int64
SeniorCitizen                              int64
Partner                                    int64
Dependents                                 int64
tenure                                     int64
PhoneService                               int64
PaperlessBilling                           int64
MonthlyCharges                           float64
TotalCharges                             float64
Churn                                      int64
MultipleLines_No                           uint8
MultipleLines_No phone service             uint8
MultipleLines_Yes                          uint8
InternetService_DSL                        uint8
InternetService_Fiber optic                uint8
InternetService_No                         uint8
OnlineSecurity_No                          uint8
OnlineSecurity_No internet service         uint8
OnlineSecurity_Yes                         uint8
OnlineBackup_No                            uint8
OnlineBackup_No internet service           uint8
OnlineBackup_Yes                           uint8
DeviceProtection_No                        uint8
DeviceProtection_No internet service       uint8
DeviceProtection_Yes                       uint8
TechSupport_No                             uint8
TechSupport_No internet service            uint8
TechSupport_Yes                            uint8
StreamingTV_No                             uint8
StreamingTV_No internet service            uint8
StreamingTV_Yes                            uint8
StreamingMovies_No                         uint8
StreamingMovies_No internet service        uint8
StreamingMovies_Yes                        uint8
Contract_Month-to-month                    uint8
Contract_One year                          uint8
Contract_Two year                          uint8
PaymentMethod_Bank transfer (automatic)    uint8
PaymentMethod_Credit card (automatic)      uint8
PaymentMethod_Electronic check             uint8
PaymentMethod_Mailed check                 uint8
dtype: object
```

Add new features

In [144]:

```
# Add number of services
df['extraServicesNumber'] =  df['OnlineSecurity_Yes'] + df['OnlineBackup_Yes'] +
 df['DeviceProtection_Yes'] + df['TechSupport_Yes'] + df['StreamingTV_Yes'] +
df['StreamingMovies_Yes']
df['phoneInternet'] = df['PhoneService'] * df['InternetService_DSL'] + df['Phone
Service'] * df['InternetService_Fiber optic']

# Compute duration
#df['duration'] = df['TotalCharges'] / df['MonthlyCharges']
```

Drop some features

Since we only need k-1 features for k categories. But I finally decided to merge categorical variables 'No' and 'No internet service', see #.

In [145]:

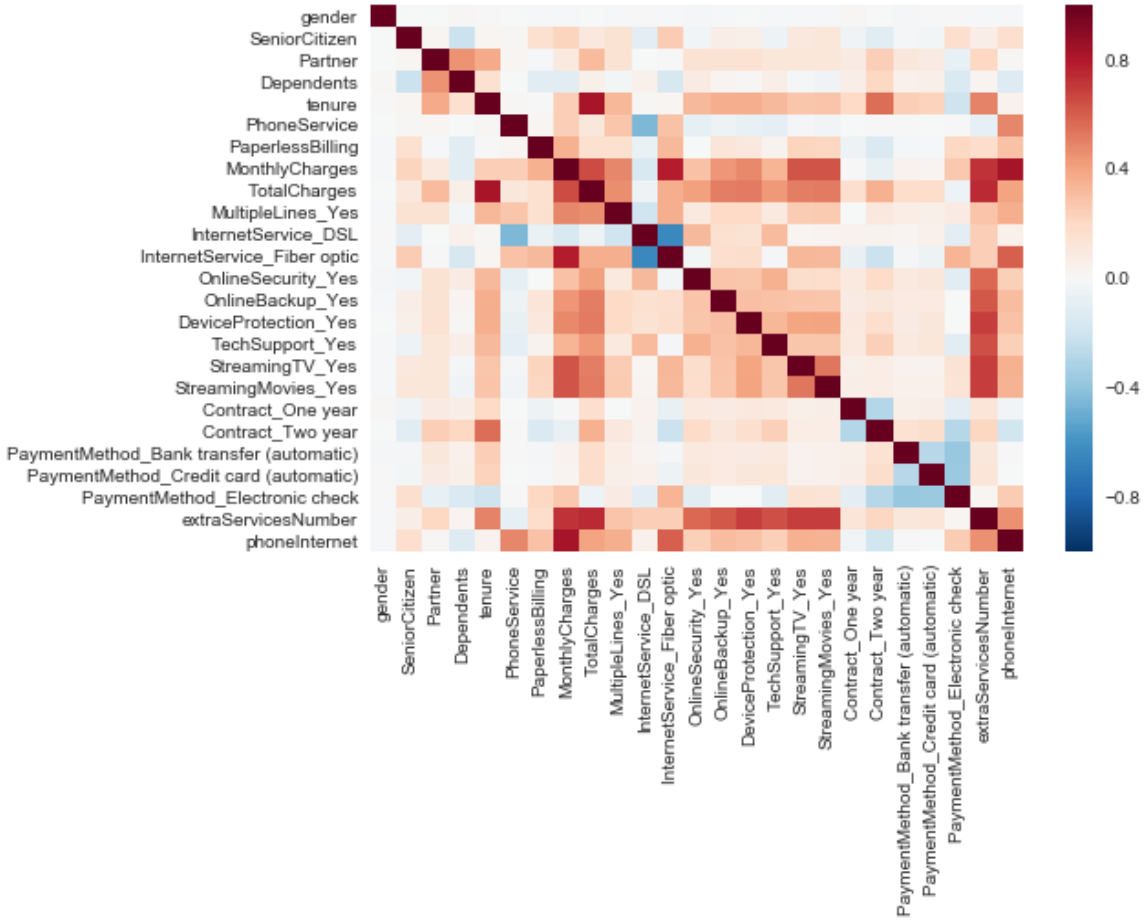
```
# Drop columns
baseline = ['MultipleLines_No phone service',
            'MultipleLines_No', #
            'InternetService_No',
            'OnlineSecurity_No internet service',
            'OnlineSecurity_No', #
            'OnlineBackup_No internet service',
            'OnlineBackup_No', #
            'DeviceProtection_No internet service',
            'DeviceProtection_No', #
            'TechSupport_No internet service',
            'TechSupport_No', #
            'StreamingTV_No internet service',
            'StreamingTV_No', #
            'StreamingMovies_No internet service',
            'StreamingMovies_No', #
            'Contract_Month-to-month',
            'PaymentMethod_Mailed check'
           ]
df.drop(baseline, axis = 1, inplace = True)

# Print all available columns
for c in list(df.columns.values):
    print(c)
```

```
gender
SeniorCitizen
Partner
Dependents
tenure
PhoneService
PaperlessBilling
MonthlyCharges
TotalCharges
Churn
MultipleLines_Yes
InternetService_DSL
InternetService_Fiber optic
OnlineSecurity_Yes
OnlineBackup_Yes
DeviceProtection_Yes
TechSupport_Yes
StreamingTV_Yes
StreamingMovies_Yes
Contract_One year
Contract_Two year
PaymentMethod_Bank transfer (automatic)
PaymentMethod_Credit card (automatic)
PaymentMethod_Electronic check
extraServicesNumber
phoneInternet
```

Display correlation

In [146]:

```
# Display correlation
corr = sns.heatmap(df.drop('Churn', axis = 1).corr())

# Rotate axes
for text in corr.get_yticklabels():
    text.set_rotation('horizontal')
for text in corr.get_xticklabels():
    text.set_rotation('vertical')
plt.show()
```



Split data into test set and train set

I use a SMOTE technique for creating balanced a balanced set. Many other methods exists, see http://contrib.scikit-learn.org/imbalanced-learn/ (http://contrib.scikit-learn.org/imbalanced-learn/).

In [147]:

```
# Separate features from target
X_imb = df.drop('Churn', axis = 1)
y_imb = df['Churn']

# Create balanced set using SMOTE
rus = SMOTE(random_state = 64)
X, y = rus.fit_sample(X_imb, y_imb)
# IMPORTANT: X and y are numpy arrays while X_imb and y_imb are data frames.

# Create train set and test set
from sklearn.cross_validation import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.2, rando
m_state = 13)
```

Feature selection

Many possibilities exists for selecting features:

- univariate tests (SelectKBest)
- RFE
- ...

In [148]:

```
# Train tree classifier
model = ExtraTreesClassifier(n_estimators = 200, random_state = 13)
model.fit(X_train, y_train)
importances = model.feature_importances_

support = importances > np.mean(importances)
selected_feature_flag = dict(zip(X_imb.columns, support))
selected_features = [k for k,v in selected_feature_flag.items() if v == True]
print(selected_features)

# Apply feature selection on train and test sets
X_train = X_train[:, support]
X_test = X_test[:, support]
```

```
['tenure', 'PaperlessBilling', 'MonthlyCharges', 'TotalCharges', 'In
ternetService_Fiber optic', 'Contract_One year', 'Contract_Two yea
r', 'PaymentMethod_Electronic check']
```

Logistic regression (using scikit-learn)

In [149]:

```
# Train
log_reg = linear_model.LogisticRegression(C=100)
log_reg.fit(X_train, y_train)

print('\nCoefficients: ',log_reg.coef_)
```

```
Coefficients:  [[ -5.45793962e-02   5.35491611e-01   5.95321086e-03
  2.81846148e-04
    8.20671032e-01  -9.49768472e-01  -1.79949176e+00   6.35281623e-0
1]]
```

In [150]:

```
print(np.exp(log_reg.coef_))
```

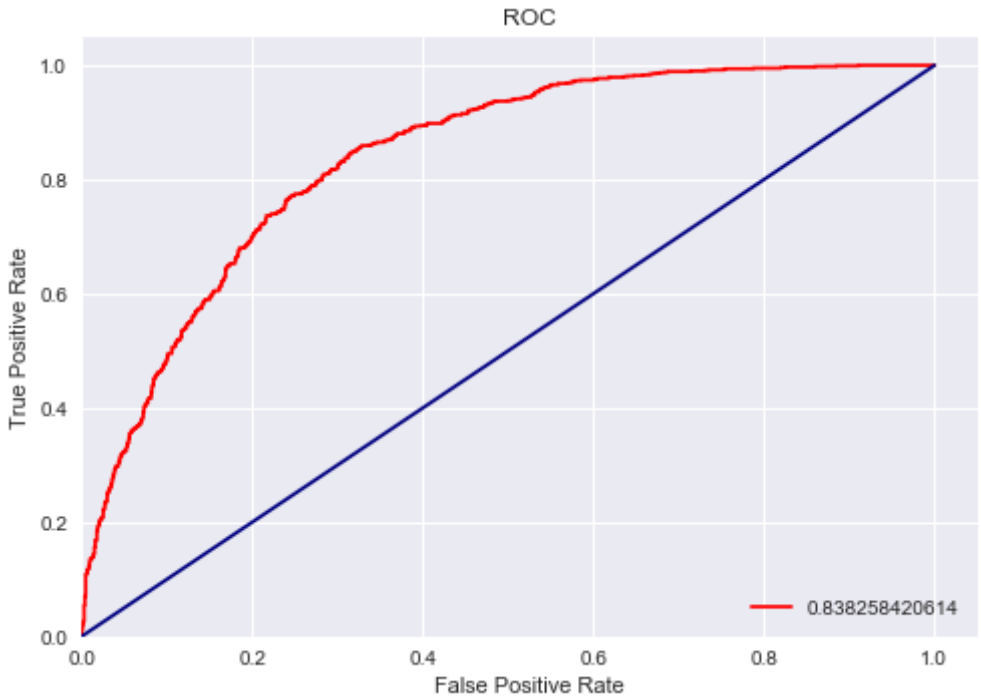
```
[[ 0.94688333  1.70828785  1.00597097  1.00028189  2.27202393  0.386
83058
   0.16538292  1.88755365]]
```

In [151]:

```
def evaluate_model(_X_test, _y_test, _y_hat):

    # ROC
    FP_rate, TP_rate, thresholds = roc_curve(_y_test, _y_hat)
    roc_auc = auc(FP_rate, TP_rate)
    plt.plot(FP_rate, TP_rate, 'r', label=roc_auc)
    plt.title('ROC')
    plt.legend(loc='lower right')
    plt.plot([0,1],[0,1],'navy')
    plt.xlim([0.0,1.05])
    plt.ylim([0.0,1.05])
    plt.ylabel('True Positive Rate')
    plt.xlabel('False Positive Rate')
    plt.show()

    # Convert to class
    _y_hat = (_y_hat > 0.5).astype('int')

    # Metrics
    print('\nReport', classification_report(_y_test, _y_hat))
    print('\nAccuracy', accuracy_score(_y_test, _y_hat))
    print('\nConfusion matrix', confusion_matrix(_y_test, _y_hat))
```

In [152]:

```
# Predict proba
y_hat = log_reg.predict_proba(X_test)[:, 1]

# Evaluate
evaluate_model(X_test, y_test, y_hat)
```




```
Report              precision    recall  f1-score   support

          0       0.79      0.72      0.75      1067
          1       0.73      0.80      0.76      1003

avg / total       0.76      0.76      0.76      2070


Accuracy 0.757971014493

Confusion matrix [[768 299]
 [202 801]]
```

Logistic regression (using statsmodels)

I like statsmodels version of the logistic regression because of its result summary.

In [153]:

```
import statsmodels.api as sm

# Convert to data frame
X_train_df = pd.DataFrame(X_train, columns = selected_features)

# Train model
log_reg_sm = sm.Logit(y_train, X_train_df)
results_sm = log_reg_sm.fit()
```

```
Optimization terminated successfully.
         Current function value: 0.480541
         Iterations 7
```