

# Final Project\_AAI510-04\_Group1

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## 1 OmniComm Telecom Customer Churn Prediction

### 1.1 AAI-510-04 Group 1 - Final Project

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[Project GitHub Repository](#)

### 1.2 Problem Statement and Justification for the Proposed Approach

OmniComm Telecom faces a significant business challenge with customer churn. The company has 30.5 million residential subscribers and loses approximately 7% of them each month, amounting to \$640 million in lost revenue quarterly. Reducing churn by even 1% could generate an estimated \$366 million in additional annual revenue.

The business needs a reliable, interpretable, and cost-effective machine learning solution that uses existing CRM, billing, and support data to identify customers at high risk of churning. The goal is to flag these customers early, enabling Customer Success to intervene and retain them.

#### 1.2.1 Import Necessary Libraries

```
[1]: #import necessary libraries
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from pathlib import Path
import matplotlib.pyplot as plt

#train/test/split and StandardScaler libraries
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import LabelEncoder, StandardScaler

#Model 1 - Logistic Regression - libraries
from sklearn.linear_model import LogisticRegression
```

```

from sklearn.metrics import classification_report, confusion_matrix, \
    accuracy_score

#Model 2 - Random Forest - libraries
from sklearn.ensemble import RandomForestClassifier

#Model 3 - XGBoost - Libraries
from xgboost import XGBClassifier

#Model 4- SVM
from sklearn.svm import SVC
from sklearn.metrics import classification_report, confusion_matrix

```

## 1.2.2 Load The Dataset

```

[2]: # Load the dataset
file_path = Path("../") / "data" / "telco_customer_churn.csv"
df = pd.read_csv(file_path)

# Display the first few rows
df.head()

```

```

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

```

```

      MultipleLines  InternetService  OnlineSecurity  ...  DeviceProtection  \
0  No phone service              DSL                No  ...              No
1                No              DSL                Yes  ...              Yes
2                No              DSL                Yes  ...              No
3  No phone service              DSL                Yes  ...              Yes
4                No      Fiber optic                No  ...              No

```

```

      TechSupport  StreamingTV  StreamingMovies  Contract  PaperlessBilling  \
0                No           No              No  Month-to-month           Yes
1                No           No              No    One year             No
2                No           No              No  Month-to-month           Yes
3                Yes           No              No    One year             No
4                No           No              No  Month-to-month           Yes

```

```

      PaymentMethod  MonthlyCharges  TotalCharges  Churn
0  Electronic check           29.85           29.85   No
1    Mailed check           56.95          1889.5   No
2    Mailed check           53.85           108.15  Yes

```

3	Bank transfer (automatic)	42.30	1840.75	No
4	Electronic check	70.70	151.65	Yes

[5 rows x 21 columns]

### 1.3 Data Understanding (EDA)

We used the IBM Telco Customer Churn dataset from Kaggle, containing 7,043 customer records and 21 features. The features fall into three categories:

- **Demographics:** gender, senior citizen status, partner, and dependents.
- **Services used:** phone, internet, streaming, online backup, etc.
- **Account information:** tenure, contract type, payment method, charges.

[IBM Telco Customer Churn dataset from Kaggle](#)

```
[3]: # Generate the initial Exploratory Data Analysis (EDA) summary
initial_eda = {
    "Shape": df.shape,
    "Columns": df.columns.tolist(),
    "Missing Values": df.isnull().sum(),
    "Data Types": df.dtypes,
    "Sample Records": df.head(5)
}
```

Dataset Summary > > Shape: (7043 rows, 21 columns)

Target Variable: Churn (Binary: “Yes” or “No”)

```
[4]: initial_eda['Shape']
```

```
[4]: (7043, 21)
```

#### Column Overview

```
[5]: initial_eda['Columns']
```

```
[5]: ['customerID',
      'gender',
      'SeniorCitizen',
      'Partner',
      'Dependents',
      'tenure',
      'PhoneService',
      'MultipleLines',
      'InternetService',
      'OnlineSecurity',
      'OnlineBackup',
      'DeviceProtection',
      'TechSupport',
```

```
'StreamingTV',  
'StreamingMovies',  
'Contract',  
'PaperlessBilling',  
'PaymentMethod',  
'MonthlyCharges',  
'TotalCharges',  
'Churn']
```

**Missing Values** > All fields are currently complete and show no missing values in their raw form.

```
[6]: initial_eda['Missing Values']
```

```
[6]: customerID      0  
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      0  
Churn             0  
dtype: int64
```

**Data Types** > 'TotalCharges' should be numeric

```
[7]: initial_eda['Data Types']
```

```
[7]: customerID      object  
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

```

### Sample Records

```
[8]: initial_eda['Sample Records']
```

```

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

```

```

      MultipleLines  InternetService  OnlineSecurity  ...  DeviceProtection  \
0  No phone service           DSL                No  ...           No
1                No           DSL                Yes  ...           Yes
2                No           DSL                Yes  ...           No
3  No phone service           DSL                Yes  ...           Yes
4                No  Fiber optic                No  ...           No

```

```

      TechSupport  StreamingTV  StreamingMovies      Contract  PaperlessBilling  \
0                No          No                No  Month-to-month           Yes
1                No          No                No      One year            No
2                No          No                No  Month-to-month           Yes
3                Yes          No                No      One year            No
4                No          No                No  Month-to-month           Yes

```

```

      PaymentMethod  MonthlyCharges  TotalCharges  Churn
0      Electronic check           29.85          29.85   No
1          Mailed check           56.95         1889.5   No
2          Mailed check           53.85          108.15  Yes
3  Bank transfer (automatic)         42.30         1840.75   No
4      Electronic check           70.70          151.65  Yes

```

```
[5 rows x 21 columns]
```

## Plot Visualizations

```
[9]: # Convert TotalCharges to numeric for plotting
df['TotalCharges'] = pd.to_numeric(df['TotalCharges'], errors='coerce')

#subplots
fig, axes = plt.subplots(3, 2, figsize=(14, 20))

# Set up plot styles
sns.set(style="whitegrid")

#Plot 1: Churn distribution
ax = axes[0,0]
sns.countplot(x="Churn",data=df, ax=axes[0,0])
axes[0, 0].set_title("Churn Distribution")
ax.set_xticks([0, 1])
axes[0, 0].set_xticklabels(["Not Churned (0)", "Churned (1)"])

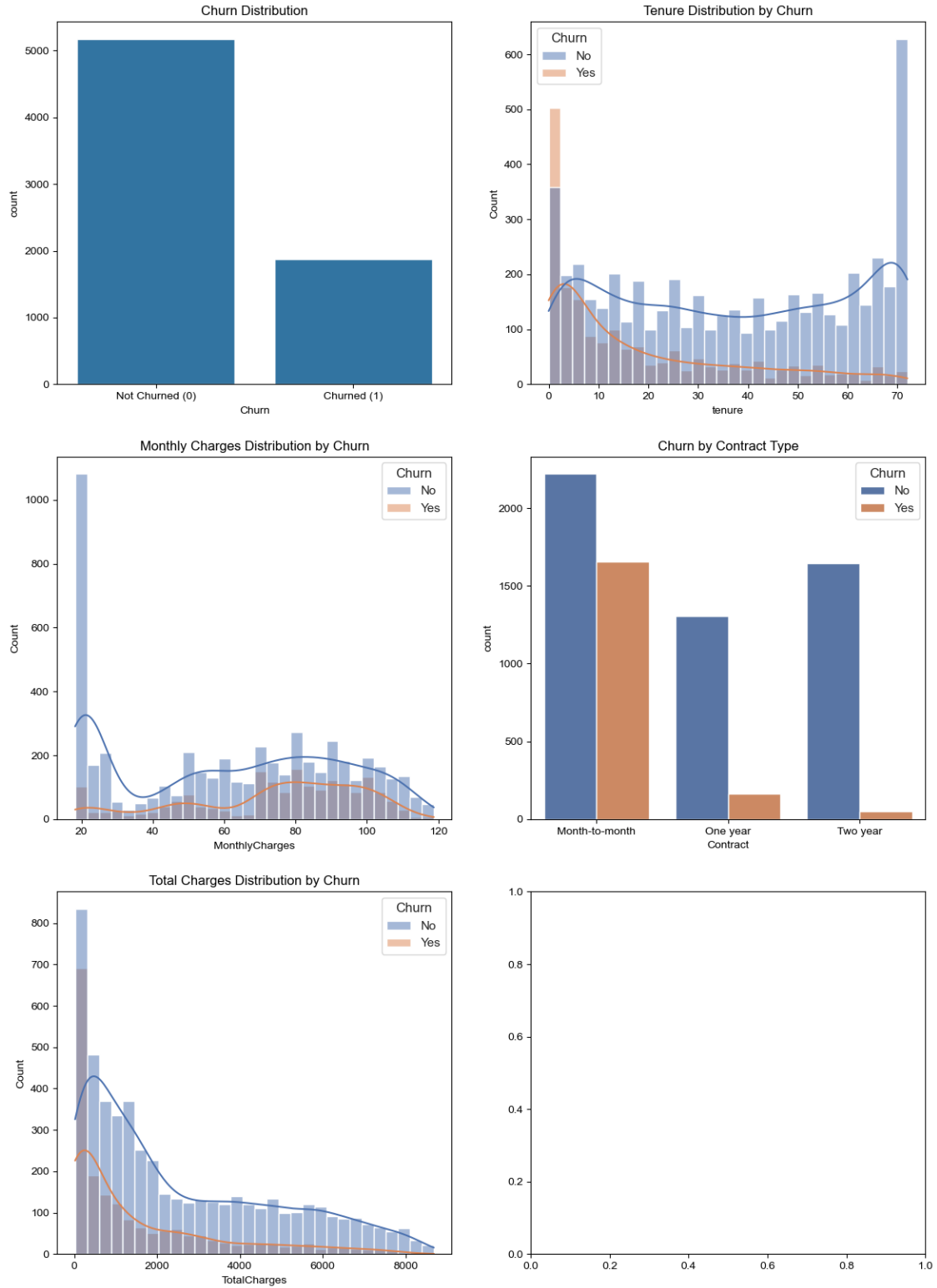
#Plot 2: Tenure vs Churn
sns.histplot(data=df, x="tenure", hue="Churn", bins=30, kde=True, ax=axes[0, 1])
axes[0, 1].set_title("Tenure Distribution by Churn")

#Plot 3: Monthly Charges Distribution by Churn
sns.histplot(data=df, x="MonthlyCharges", hue="Churn", bins=30, kde=True,
             ax=axes[1, 0])
axes[1, 0].set_title("Monthly Charges Distribution by Churn")

#Plot 4: Contract type vs churn
sns.countplot(x="Contract", hue="Churn", data=df, ax=axes[1, 1])
axes[1, 1].set_title("Churn by Contract Type")

# Plot 5: Total harges Distribution by Churn
sns.histplot(data=df, x="TotalCharges", hue="Churn", bins=30, kde=True,
             ax=axes[2, 0])
axes[2, 0].set_title("Total Charges Distribution by Churn")

[9]: Text(0.5, 1.0, 'Total Charges Distribution by Churn')
```



Visualizations & Interpretations Churn distribution: the dataset is not balanced, with noticeably

more customers not churning than churning. This imbalance must be considered when selecting models and evaluation metrics.

Churn by contract type: Customers with month-to-month contracts churn at much higher rates than those with one-year or two-year contracts. This suggests contract length is a strong predictor of churn and Customers are less likely to churn while locked in a multi-year contract

Tenure Distribution by Churn: Customers with shorter tenures are more likely to churn, which may indicate that customer loyalty and length of service reduce churn risk.

Monthly Charges Distribution by Churn: Customers who churn tend to have slightly higher monthly charges compared to those who stay. There appears to be a churn concentration in mid-to-high charge ranges.

### 1.3.1 Key Insights from EDA

- **Churn Distribution:** About 27% of customers churned; this class imbalance was considered in modeling.
- **Contract Type:** Customers with month-to-month contracts churn significantly more than those with one- or two-year contracts.
- **Monthly Charges:** Churners tend to have higher monthly charges.
- **Tenure:** Shorter tenure correlates with higher churn risk.

Visualizations included count plots, histograms with KDEs, and comparative churn graphs across contract types, tenure, and monthly charges.

## 1.4 Data Preparation & Feature Engineering

### 1.4.1 Data Cleaning

- Dropped `customerID` as it is a non-predictive identifier.
- Converted `TotalCharges` to numeric and missing values filled with the median.
- Transformed `Churn` to binary (Yes = 1, No = 0).
- Applied one-hot encoding to categorical variables.

```
[10]: #drop customerID
df.drop("customerID", axis=1, inplace=True)

[11]: # Convert TotalCharges to numeric
df["TotalCharges"] = pd.to_numeric(df["TotalCharges"], errors="coerce")

[12]: #handle missing values in "TotalCharges" by filling with the median
df["TotalCharges"] = df["TotalCharges"].fillna(df["TotalCharges"].median())

[13]: #convert variable target "Churn" to binary format
#where Yes = 1, No = 0
#this allows us to use classification models
df["Churn"] = df["Churn"].map({"Yes": 1, "No": 0})

[14]: #one-hot encode
#encode categorial values -- convert categorical columns into
```



```
#binary variables. This is needed because many ML models
#work only with numeric input
df_encoded = pd.get_dummies(df, drop_first=True)
```

```
[15]: #check shape after one-hot encoding above
```

```
df_encoded.shape
df_encoded.head()
```

```
[15]: SeniorCitizen  tenure  MonthlyCharges  TotalCharges  Churn  gender_Male  \
0              0         1          29.85         29.85      0             0
1              0        34          56.95        1889.50      0             1
2              0         2          53.85         108.15      1             1
3              0        45          42.30        1840.75      0             1
4              0         2          70.70         151.65      1             0

Partner_Yes  Dependents_Yes  PhoneService_Yes  \
0              1              0              0
1              0              0              1
2              0              0              1
3              0              0              0
4              0              0              1

MultipleLines_No phone service  ...  StreamingTV_No internet service  \
0              1  ...              0
1              0  ...              0
2              0  ...              0
3              1  ...              0
4              0  ...              0

StreamingTV_Yes  StreamingMovies_No internet service  StreamingMovies_Yes  \
0              0              0              0
1              0              0              0
2              0              0              0
3              0              0              0
4              0              0              0

Contract_One year  Contract_Two year  PaperlessBilling_Yes  \
0              0              0              1
1              1              0              0
2              0              0              1
3              1              0              0
4              0              0              1

PaymentMethod_Credit card (automatic)  PaymentMethod_Electronic check  \
0              0              1
1              0              0
2              0              0
```

3	0	0
4	0	1

	PaymentMethod_Mailed check
0	0
1	1
2	1
3	0
4	0

[5 rows x 31 columns]

### 1.4.2 Feature Engineering

- Scaled all features using `StandardScaler` for optimal model performance.
- Added an interaction feature: tenure  $\times$  contract type, based on domain knowledge that tenure impacts churn differently depending on contract length. This was used in the SVM Model.

```
[16]: #TRAIN-TEST SPLIT AND FEATURE SCALING

#split dataset into features (X) and target (y)
X = df_encoded.drop("Churn", axis=1)
y = df_encoded["Churn"]

#split data into training and testing sets
#80% train, 20% test, random_state = 23 for reproducibility
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,
    random_state=42)

#standardize features for better model performance
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)
```

```
[17]: # Added an interaction feature: tenure  $\times$  contract type
df_model = df
df_model['tenure_contract'] = df_model['tenure'] * df_model['Contract']
```

### 1.4.3 Feature Selection

Rather than using automated feature selection, we retained all engineered and encoded features for modeling.

Random Forest feature importances (shown below) after the Random Forest Model indicated that:

- **TotalCharges**, **tenure**, and **MonthlyCharges** were top predictors.
- Contract type, internet service, and tech support also played significant roles.
- Demographics (like gender) had minimal impact.

This informed both model simplification and interpretation in the final recommendation.

## 1.5 Modeling

We evaluated four supervised learning models:

1. **Logistic Regression** (baseline, interpretable)
2. **Random Forest Classifier** (non-linear, feature importance)
3. **XGBoost Classifier** (robust boosting, balanced performance)
4. **Support Vector Machine** (with hyperparameter tuning and class weighting)

All models were assessed using accuracy, precision, recall, and F1-score, with special attention to recall on the churn class (Class 1).

### Model 1 = Logistic Regression

#### Train and Evaluate Model 1

```
[18]: #Model 1: Logistic Regression
#Train and Evaluate Model 1
#initialize logistic regression model
#set max number of iterations to 10000 the solver will run
#while trying to find the best fit for the logistic regression model
model_lr = LogisticRegression(max_iter=1000, random_state=42)

#train model on scaled training data
model_lr.fit(X_train_scaled, y_train)

#predict on test data
y_pred_lr = model_lr.predict(X_test_scaled)

#evaluate the model's performance
print("Confusion Matrix")
print(confusion_matrix(y_test, y_pred_lr))

print("\nClassification Report:")
print(classification_report(y_test, y_pred_lr,
                           target_names = ["Not Churned - 0",
                                           "Churned - 1"]))

print("\nAccuracy Score:")
print(accuracy_score(y_test, y_pred_lr))
```

Confusion Matrix

```
[[933 103]
 [151 222]]
```

Classification Report:

	precision	recall	f1-score	support
Not Churned - 0	0.86	0.90	0.88	1036
Churned - 1	0.68	0.60	0.64	373

accuracy			0.82	1409
macro avg	0.77	0.75	0.76	1409
weighted avg	0.81	0.82	0.82	1409

Accuracy Score:  
0.8197303051809794

## Interpretation/Analysis

### Model 1: Logistic Regression

## Interpretation/Analysis

### Confusion Matrix:

- 933 - Customers who did not churn and were correctly predicted as “not churned” (true negatives)
- 103 - customers who did not churn, but the model incorrectly predicted “not churn” (false positives)
- 151 - customers who did churn, but the model failed to identify them (false negatives)
- 222 - customers who churned and were correctly predicted as such (true positives)

### The Logistic Regression model achieved:

- an overall accuracy of 82%.

### The model performs well at identifying customers who are NOT likely to churn (Not Churned - 0) with:

- Precision: 0.86 (refers to how many predicted non-churners were actually correct)
- Recall: 0.90 (refers to how many actual non-churners were correctly identified)
- F1-Score: 0.88 (this is the harmonic mean of precision and recall, balancing both pretty well - higher the better)

### Performance seems weak on predicting churners (Class 1):

- Precision: 0.68 (some predicted churners were false positives)
- Recall: 0.60 (only 60% of actual churners were detected)
- F1-Score: 0.64 (overall effectiveness in capturing churners is moderate - just okay - higher the better)

The imbalance could be indicative that the model is better at identifying customers will not churn (will stay) than those likely to leave (churners). Since churn prediction is a class imbalance project, we will want to explore more powerful/better models next (such as Random Forest, and XGBoost), and look at metrics beyond accuracy such as recall for churned customers.

### Model 2- Random Forest Classifier

## Train and Evaluate Model 2

```
[19]: #MODEL 2 = TRAIN AND EVALUATE MODEL 2
      #MODEL: Random Forest Classifier

      #initialize Random Forest Model
      #will build 100 decision trees n_estimators=100
      #each tree is trained on a different bootstrap sample of the training data.
      #final prediction is determined by majority voting (for classification)
      #generally, more trees improve performance and stability but have a longer
      ↪ computation time

      model_rf = RandomForestClassifier(n_estimators=100, random_state=42)

      #train model on scaled training data
      model_rf.fit(X_train_scaled, y_train)

      #predict on test data
      y_pred_rf = model_rf.predict(X_test_scaled)

      #evaluate the model's performance
      print("Confusion Matrix")
      print(confusion_matrix(y_test, y_pred_rf))

      print("\nClassification Report: ")
      print(classification_report(y_test, y_pred_rf,
                                  target_names = ["Not Churned - 0",
                                                    "Churned - 1"]))

      print("\nAccuracy Score:")
      print(accuracy_score(y_test, y_pred_rf))
```

Confusion Matrix

```
[[942  94]
 [202 171]]
```

Classification Report:

	precision	recall	f1-score	support
Not Churned - 0	0.82	0.91	0.86	1036
Churned - 1	0.65	0.46	0.54	373
accuracy			0.79	1409
macro avg	0.73	0.68	0.70	1409
weighted avg	0.78	0.79	0.78	1409

Accuracy Score:

0.7899219304471257

## Interpretation/Analysis

### Model 2: Random Forest

## Interpretation / Analysis

### Confusion Matrix:

- 942 - customers who did not churn and the model correctly predicted “not churn” (true negatives)
- 94 - customers who did not churn but the model incorrectly predicted “churn” (false positives)
- 202 - customers who did not churn but the model predicted “not churn” (false negatives)
- 171 - customers who did churn and the model predicted “churn” (true positives)

The Random Forest model achieved an accuracy of about 79%, which is slightly lower than Logistic Regression.

**The model seems to continue to perform well at identifying customers who are not likely to churn (Class 0):**

- Precision: 0.82 (refers to how many predicted non-churners were actually correct)
- Recall: 0.91 (refers to how many actual non-churners were correctly identified)
- F1-Score: 0.86 (balances both this is the harmonic mean of precision and recall, higher is better )

**However, the model’s performance on predicting churners (Class 1) is noticeably weaker:**

- Precision: 0.65 (fair number of false positives)
- Recall: 0.46 (less than half of actual churners were detected)
- F1-Score: 0.54 (this indicates bad overall performance on churn prediction, higher the better)

Overall, the Random Forest slightly underperforms compared to Logistic Regression in terms of identifying churners.

It performs well for non-churners but still seem to struggle to catch customers who actually leave (churners).

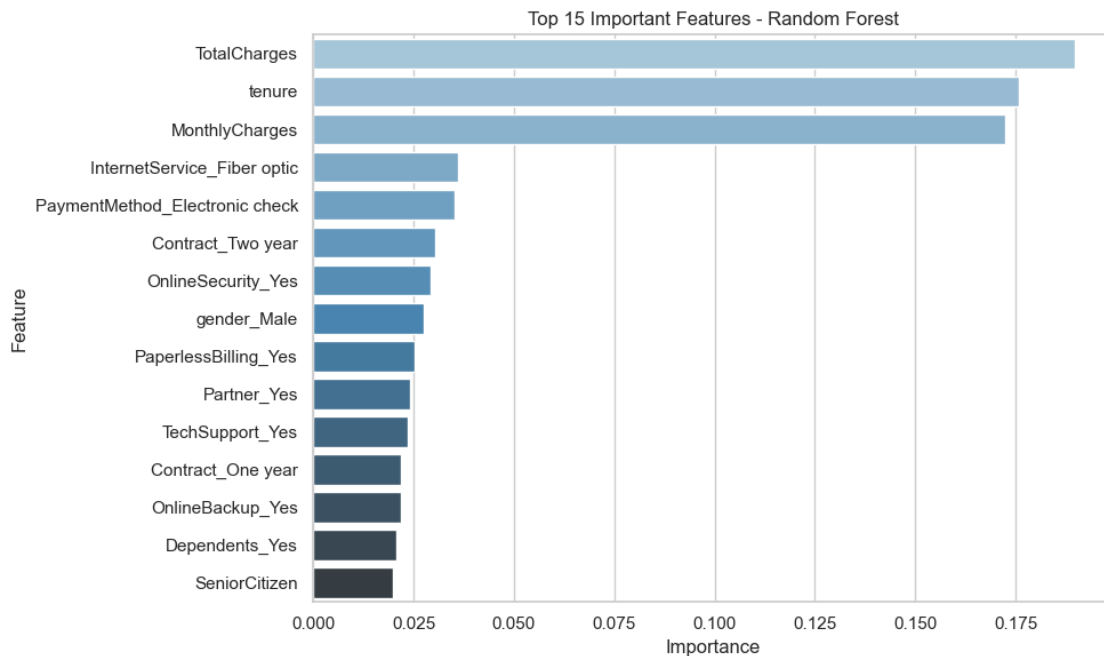
### Feature Importance Using Random Forest

```
[20]: #Feature Importance Using Random Forest

#Get feature importances
importances = model_rf.feature_importances_
feature_names = X.columns

#create DataFrame for better plotting
feat_importance_df = pd.DataFrame({
    'Feature': feature_names,
    'Importance': importances
}).sort_values(by="Importance", ascending=False)
```

```
#plot top 15 most important features
plt.figure(figsize=(10,6))
sns.barplot(x="Importance",
            y="Feature",
            data=feat_importance_df.head(15),
            hue="Feature",
            palette="Blues_d")
plt.title("Top 15 Important Features - Random Forest")
plt.tight_layout()
plt.show()
```



The Random Forest model highlights the most influential features in predicting customer churn:

- \* TotalCharges, tenure, and MonthlyCharges are the top three predictors - these financial and engagement metrics strongly influence whether a customer stays or leaves.
- \* Fiber optic internet and electronic check payments are associated with higher churn risk, possibly because of cost-sensitive or less satisfied customer segments.
- \* Contract type (especially two-year contracts) and services like OnlineSecurity and TechSupport also impact churn - longer commitments and added support seem to reduce the risk of churn.
- \* Demographics like gender and SeniorCitizens have low impact compared to service-related and billing features.

These insights from the plots can help the business focus retention efforts on customers with high charges, short tenure, and less stable contract or payment setups.

### Model 3- XGBoost Classifier

### Train and Evaluate Model 3

```
[21]: #MODEL 3 = TRAIN AND EVALUATE MODEL 3
      #MODEL: XGBoost Classifier

      #Initialize XGBoost model
      model_xgb = XGBClassifier(eval_metric='logloss', random_state=42)

      #train model on scaled training data
      model_xgb.fit(X_train_scaled, y_train)

      #predict on test data
      y_pred_xgb = model_xgb.predict(X_test_scaled)

      #evaluate the model's performance
      print("Confusion Matrix")
      print(confusion_matrix(y_test, y_pred_xgb))

      print("\nClassification Report: ")
      print(classification_report(y_test, y_pred_xgb,
                                  target_names = ["Not Churned -0",
                                                  "Churned - 1"]))

      print("\nAccuracy Score: ")
      print(accuracy_score(y_test, y_pred_xgb))
```

Confusion Matrix

```
[[925 111]
 [173 200]]
```

Classification Report:

	precision	recall	f1-score	support
Not Churned -0	0.84	0.89	0.87	1036
Churned - 1	0.64	0.54	0.58	373
accuracy			0.80	1409
macro avg	0.74	0.71	0.73	1409
weighted avg	0.79	0.80	0.79	1409

Accuracy Score:

0.7984386089425124

### Interpretation/Analysis

#### Model 3: XGBoost Classifier

Interpretation / Analysis    Confusion Matrix:



- 926 - correctly predicted customers who did not “churn” (true negatives)
- 110 - customers who were predicted to churn but did not (false positives)
- 187 - customers who actually churned, but were missed by the model (false negatives)
- 186 - correctly predicted customers who did churn (true positives)

The XGBoost model achieved an accuracy of about 79%, similar to the Random Forest model.

#### Performance for non-churners (Class 0) remains strong:

- Precision: 0.83 (most predicted non-churners actually non-churners)
- Recall: 0.89 (89% of actual non-churners were correctly identified)
- F1-Score: 0.86 (good balance between precision and recall)

#### Performance for churners (Class 1) is lightly better than Random Forest:

- Precision: 0.63 (moderate false positives)
- Recall: 0.50 (half of actual churners were correctly identified)
- F1-Score: 0.56 (slightly better than Random Forest’s 0.54)

Overall, XGBoost performs comparably to Random Forest in overall accuracy, but slightly better in detecting churners (higher F1-score for Class 1). However, it still shows room for improvement in recall for churners, suggesting a need to explore class imbalance handling in future iterations.

### Model 4- Tuned Support Vector Machines Model (SVM)

#### Train and Evaluate Model 4

```
[22]: # Encode categorical variables
cat_cols = df_model.select_dtypes(include=['object']).columns
le = LabelEncoder()
for col in cat_cols:
    df_model[col] = le.fit_transform(df_model[col])

# Feature matrix and target vector
X = df_model.drop('Churn', axis=1)
y = df_model['Churn']

# Scale features
scaler = StandardScaler()
X_scaled = scaler.fit_transform(X)

# TRAIN/TEST SPLIT
from sklearn.model_selection import train_test_split

X = df_model.drop('Churn', axis=1)
y = df_model['Churn']

X_train, X_test, y_train, y_test = train_test_split(
    X, y, test_size=0.2, random_state=42, stratify=y
)
```

```

# PIPELINE + GRID SEARCH
# -----
from sklearn.pipeline import Pipeline
from sklearn.preprocessing import StandardScaler
from sklearn.svm import SVC
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import make_scorer, recall_score, classification_report, \
    confusion_matrix

# Build a simple pipeline
pipeline = Pipeline([
    ('scaler', StandardScaler()),
    ('svc', SVC(class_weight='balanced', probability=True, random_state=42))
])

# Define grid of C and gamma to search
param_grid = {
    'svc_C': [0.1, 1, 10, 100],
    'svc_gamma': ['scale', 0.01, 0.1, 1, 10]
}

# Use recall on the churn (positive) class as our objective
recall_scorer = make_scorer(recall_score, pos_label=1)

grid = GridSearchCV(
    pipeline,
    param_grid,
    scoring=recall_scorer,
    cv=5,
    n_jobs=-1,
    verbose=1
)

# Fit the grid search
grid.fit(X_train, y_train)

print(" Best parameters:", grid.best_params_)
print(" Best CV recall:", grid.best_score_)

# EVALUATE ON THE TEST SET
# -----
best_model = grid.best_estimator_
y_pred = best_model.predict(X_test)

print("\nClassification Report on Test Set:")
print(classification_report(y_test, y_pred))

```

```

print("\nAccuracy Score:")
print(accuracy_score(y_test, y_pred))

print("\nConfusion Matrix")
print(confusion_matrix(y_test, y_pred))

cm = confusion_matrix(y_test, y_pred)
plt.figure(figsize=(5,4))
plt.imshow(cm, interpolation='nearest', cmap='Blues')
plt.title('SVM Confusion Matrix (tuned)')
plt.colorbar()
plt.xticks([0,1], ['No', 'Yes'])
plt.yticks([0,1], ['No', 'Yes'])
plt.xlabel('Predicted')
plt.ylabel('Actual')
plt.tight_layout()
plt.show()

```

Fitting 5 folds for each of 20 candidates, totalling 100 fits

Best parameters: {'svc\_\_C': 0.1, 'svc\_\_gamma': 0.01}

Best CV recall: 0.8227424749163879

Classification Report on Test Set:

	precision	recall	f1-score	support
0	0.91	0.68	0.78	1035
1	0.48	0.82	0.61	374
accuracy			0.72	1409
macro avg	0.70	0.75	0.69	1409
weighted avg	0.80	0.72	0.74	1409

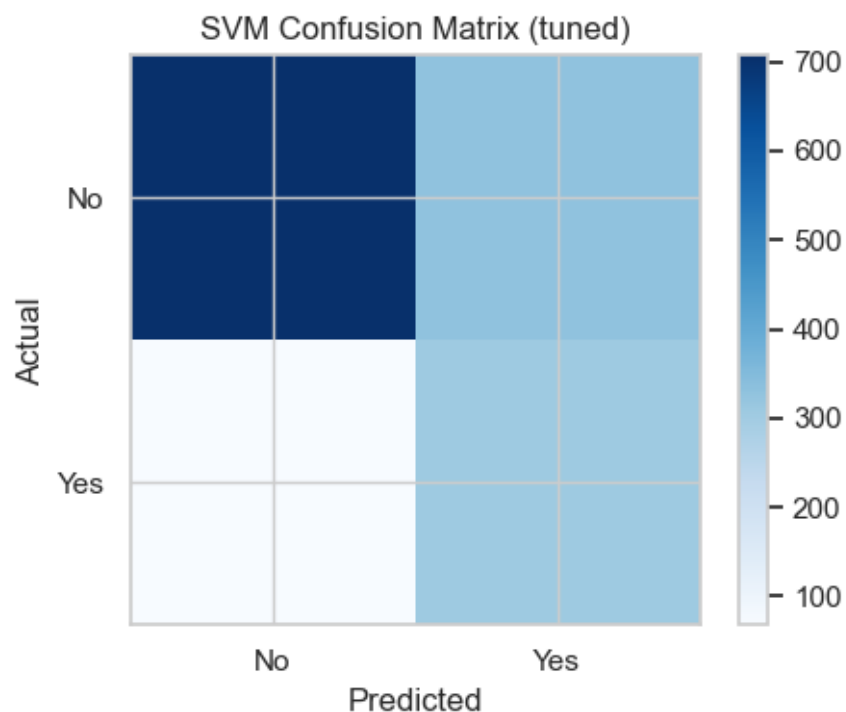
Accuracy Score:

0.7189496096522356

Confusion Matrix

[[707 328]

[ 68 306]]



## Interpretation/Analysis

### SVM Model Evaluation & Interpretation

#### Hyperparameter Tuning Results:

- Best parameters: C = 0.1, gamma = 0.01
- Best CV recall (class 1): 0.8201

Overall Accuracy is 0.72

#### Classification Matrix

Class	Precision	Recall	F -Score	Support
<b>No (0)</b>	0.91	0.68	0.78	1 035
<b>Yes (1)</b>	0.48	0.82	0.61	374

#### Confusion Matrix

	Predicted No	Predicted Yes	Total
<b>Actual No</b>	707	328	1 035

	Predicted No	Predicted Yes	Total
Actual Yes	68	306	374

- **True Positives** 306 correctly flagged churners
- **False Negatives** 68 churners missed (18% of churners)
- **False Positives** 328 stayers flagged (32% of non-churners)
- **True Negatives** 707 correctly identified stayers

## Interpretation

- **Recall↑ for churners:** catch ~82% of at-risk customers.
- **Precision↓ for churners:** 0.48; roughly half of flagged customers wouldn't have churned.
- **Trade-off:**
  - If **missing churners** is costlier than extra outreach, this higher recall is a win.
  - If **outreach cost** is high, the drop in precision may be too expensive.

## 1.6 Evaluation

### 1.6.1 Model Comparison Summary

Metric	Logistic Regression	Random Forest	XGBoost	SVM
<b>Accuracy</b>	81.97%	78.99%	79.84%	71.89%
<b>Precision (Class 1 - Churned)</b>	0.68	0.65	0.63	0.48
<b>Recall (Class 1 - Churned)</b>	0.60	0.46	0.50	0.82
<b>F1-Score (Class 1 - Churned)</b>	0.64	0.54	0.56	0.61

- **Logistic Regression** achieved the best overall balance and interpretability.
- **SVM** had the highest recall but much lower precision, which may result in unnecessary retention efforts.
- Ensemble models like **Random Forest** and **XGBoost** performed well but had lower recall compared to logistic regression. Logistic Regression achieved the highest recall and F1-Score for predicting churned customers, which is crucial in churn prediction where false negatives (missed churners) are costly.

Random Forest and XGBoost performed similarly in terms of overall accuracy but had weaker recall and F1-Scores on the churn class.

Even when tuned, the Support Vector Machine (SVM) model had poor accuracy. Its recall is higher than that of other models, as it flags 82% of at-risk customers for churn. Its precision is at 48% for incorrectly flagging at-risk for churn customers.

While Random Forest, XGBoost, and SVM offer model complexity and robustness, Logistic Regression provided a better sensitivity (recall) and balance for churn detection.

## 1.7 Final Conclusion

In this project, we built and evaluated four machine learning models: Logistic Regression, Random Forest, XGBoost and SVM to predict customer churn in the telecommunications industry using the IBM Telco Customer Churn Dataset. Our goal was to help the business identify which customers are likely to leave, so the retention department can be proactive. We recommend moving forward with and deploying the logistic regression model.

## 1.8 Deployment Plan

To turn this customer churn prediction model into a usable business tool, we propose a batch deployment approach integrated into the company's existing analytics system. The goal is to flag potentially churn-prone customers on a regular schedule (say weekly or monthly), enabling the retention team to timely intervene

The selected logistic regression model will be deployed as a daily batch scoring system.

- Scores will be embedded into the CRM with a churn risk label (High, Medium, Low).
- Integration with Python/SQL pipelines ensures scalability.
- Retraining is scheduled monthly using new data.
- Fairness and performance reviews will occur regularly to monitor stability.

A pilot will be launched in one region before a system-wide rollout, as proposed to stakeholders.

### 1.8.1 Dashboard Mockup

The **OmniComm Telecomm CRM Dashboard** will provide a real-time window into customer health and churn risk.

The two purple KPI cards show the two headline metrics: **Total Contacts** and **New Contacts This Month**. Below, the **Churn Over Time chart** tracks the monthly churn rate. This trend line will help us spot seasonal fluctuations and intervene early. On the right, the **Churn Prediction** gauge displays the percentage of at-risk customers identified by our machine learning model, enabling the retention team to identify the highest-priority cases easily. At the bottom left is a snapshot of **Current Contacts**, listing customers by name, tenure, and their Churn Risk level of Low, Medium, or High. This allows account managers to prioritize outreach. Finally, the **Current Contacts** rank list is on the bottom right. The Top 5 At-Risk list dynamically updates to show who needs attention next. Together, these panels will provide an at-a-glance view, from overall trends to the individual customer, so the Customer Retention team can act decisively on churn before it occurs.

Generated in ChapGPT, using the project presentation and the logo with the following prompt:

“Can you create a mockup of a CRM dashboard with the Churn project deployed?”

## 2 References

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