SYRIATEL CUSTOMER CHURN ANALYSIS

Business Understanding

SyriaTel is experiencing customer churn, which negatively impacts revenue and growth. This analysis aims to identify factors contributing to churn and develop strategies for customer retention.

Business Problem

Customer churn is a big problem for telecom companies because it costs more to get new customers than to keep existing ones. SyriaTel wants to find out which customers are likely to leave so they can take action to keep them.

Objectives

Classification

- **Build a model to predict customer churn (whether a customer will leave or stay).**
- **Identify key factors that influence customer churn.**
- **Improve model performance using feature selection, hyperparameter tuning, and other techniques.**

Business Insights

- **Identify high-risk customer segments.**
- **Provide actionable recommendations to reduce churn.**

Data Understanding

In [374]:

```
import pandas as pd
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import warnings
from sklearn.preprocessing import StandardScaler

warnings.filterwarnings('ignore')
```

In [375]:

```
df = pd.read_csv ('bigml_59c28831336c6604c800002a.csv')
df. head()
```

Out[375]:

	state	account length	area code	phone number	international plan	voice mail plan	number vmail messages	total day minutes	total day calls	total day charge	...	total eve calls	total eve charge	total night minutes	total night calls
0	KS	128	415	382-4657	no	yes	25	265.1	110	45.07	...	99	16.78	244.7	91
1	OH	107	415	371-7191	no	yes	26	161.6	123	27.47	...	103	16.62	254.4	103

	state	account length	area code	phone number	international plan	voice mail plan	number vmail messages	total day minutes	total day calls	total day charge	...	total eve calls	total eve charge	total night minutes	total night calls	ch
2	NJ	137	415	358-1921	no	no	0	243.4	114	41.38	...	110	10.30	162.6	104	
3	OH	84	408	375-9999	yes	no	0	299.4	71	50.90	...	88	5.26	196.9	89	
4	OK	75	415	330-6626	yes	no	0	166.7	113	28.34	...	122	12.61	186.9	121	

5 rows × 21 columns

In [376]:

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 3333 entries, 0 to 3332
Data columns (total 21 columns):
 #   Column                  Non-Null Count  Dtype  
---  ------                  --------------  -----  
 0   state                   3333 non-null   object 
 1   account length          3333 non-null   int64  
 2   area code               3333 non-null   int64  
 3   phone number            3333 non-null   object 
 4   international plan      3333 non-null   object 
 5   voice mail plan         3333 non-null   object 
 6   number vmail messages   3333 non-null   int64  
 7   total day minutes       3333 non-null   float64
 8   total day calls         3333 non-null   int64  
 9   total day charge        3333 non-null   float64
 10  total eve minutes       3333 non-null   float64
 11  total eve calls         3333 non-null   int64  
 12  total eve charge        3333 non-null   float64
 13  total night minutes     3333 non-null   float64
 14  total night calls       3333 non-null   int64  
 15  total night charge      3333 non-null   float64
 16  total intl minutes      3333 non-null   float64
 17  total intl calls        3333 non-null   int64  
 18  total intl charge       3333 non-null   float64
 19  customer service calls  3333 non-null   int64  
 20  churn                   3333 non-null   bool   
dtypes: bool(1), float64(8), int64(8), object(4)
memory usage: 524.2+ KB
```

In [377]:

```
#Summary statistics.
df.describe()
```

Out[377]:

	account length	area code	number vmail messages	total day minutes	total day calls	total day charge	total eve minutes	total eve calls	total eve charge
count	3333.000000	3333.000000	3333.000000	3333.000000	3333.000000	3333.000000	3333.000000	3333.000000	3333.000000
mean	101.064806	437.182418	8.099010	179.775098	100.435644	30.562307	200.980348	100.114311	17.083540
std	39.822106	42.371290	13.688365	54.467389	20.069084	9.259435	50.713844	19.922625	4.310668
min	1.000000	408.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
25%	74.000000	408.000000	0.000000	143.700000	87.000000	24.430000	166.600000	87.000000	14.160000
50%	101.000000	415.000000	0.000000	179.400000	101.000000	30.500000	201.400000	100.000000	17.120000
75%	127.000000	510.000000	20.000000	216.400000	114.000000	36.790000	235.300000	114.000000	20.000000
max	243.000000	510.000000	51.000000	350.800000	165.000000	59.640000	363.700000	170.000000	30.910000

In [378]:

```
#Check for missing values.
df.isnull(). sum()
```

Out[378]:

```
state                     0
account length            0
area code                 0
phone number              0
international plan        0
voice mail plan           0
number vmail messages     0
total day minutes         0
total day calls           0
total day charge          0
total eve minutes         0
total eve calls           0
total eve charge          0
total night minutes       0
total night calls         0
total night charge        0
total intl minutes        0
total intl calls          0
total intl charge         0
customer service calls    0
churn                     0
dtype: int64
```

In [379]:

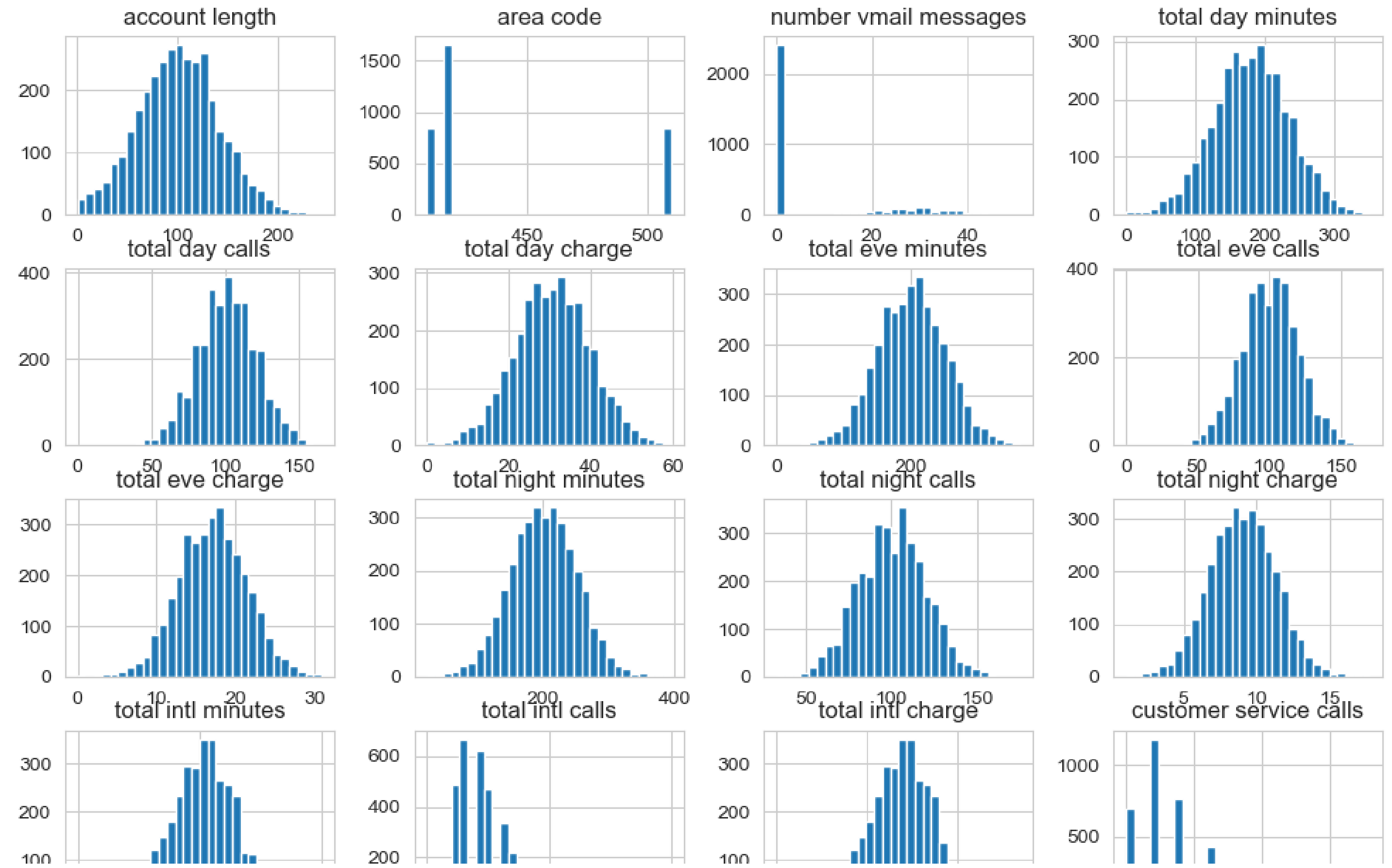
```
# Check for duplicate rows.
df.duplicated().sum()
```

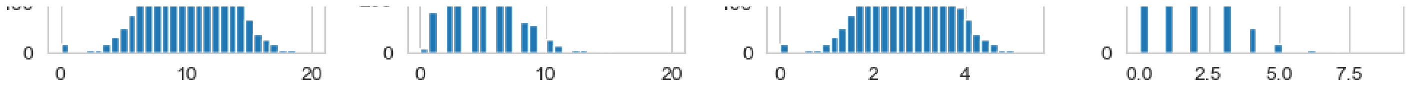
Out[379]:

```
0
```

In [380]:

```
#Data distribution
#Plotting histograms for data distribution
df.hist(figsize=(12, 8), bins=30)
plt.show()
```





Data Cleaning

Dropping columns

In [381]:

```
# Dropping the phone number column because it is not useful in my analysis.
df.drop(columns=['phone number'], inplace=True)
```

Data Formatting.

In [382]:

```
df["state"] = df["state"].astype("category")
```

In [383]:

```
# Converting international plan and voice mail plan from object to binary to make them mo
re intepretable.

df['international plan'] = df['international plan'].map({'no': 0, 'yes': 1})
df['voice mail plan'] = df['voice mail plan'].map({'no': 0, 'yes': 1})


df.head()
```

Out[383]:

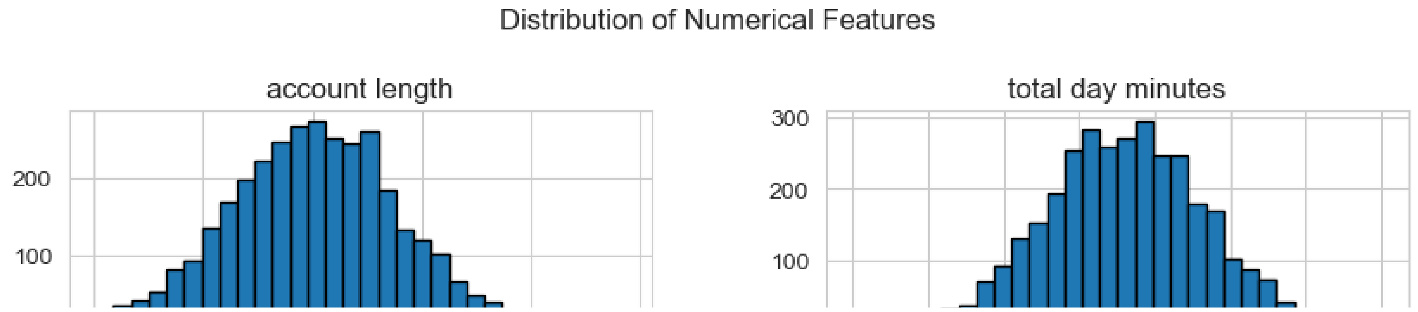
	state	account length	area code	international plan	voice mail plan	number vmail messages	total day minutes	total day calls	total day charge	total eve minutes	total eve calls	total eve charge	total night minutes	total night calls	tot nigl charg
0	KS	128	415	0	1	25	265.1	110	45.07	197.4	99	16.78	244.7	91	11.(
1	OH	107	415	0	1	26	161.6	123	27.47	195.5	103	16.62	254.4	103	11.4
2	NJ	137	415	0	0	0	243.4	114	41.38	121.2	110	10.30	162.6	104	7.3
3	OH	84	408	1	0	0	299.4	71	50.90	61.9	88	5.26	196.9	89	8.8
4	OK	75	415	1	0	0	166.7	113	28.34	148.3	122	12.61	186.9	121	8.4

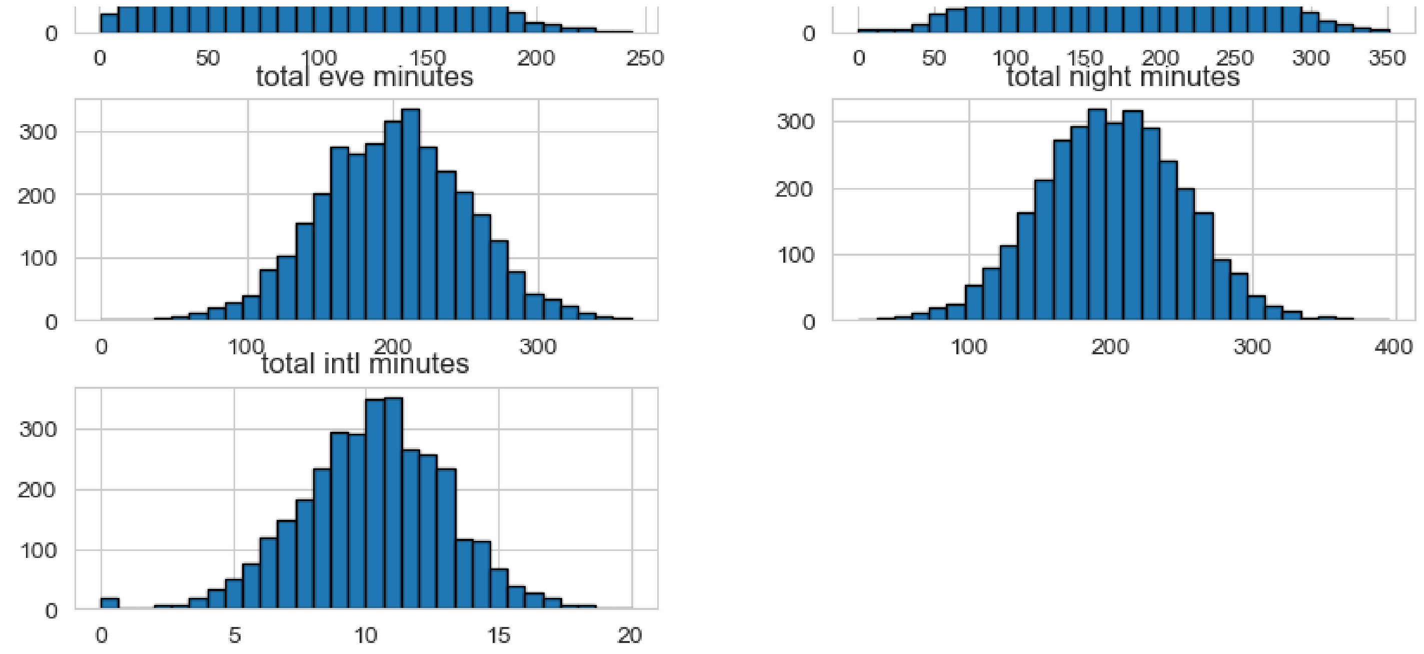
In [384]:

```
# Checking the distribution of key numerical features such as account length, total charg
es, and minutes used.

# Histogram for numerical features
num_features = ['account length', 'total day minutes', 'total eve minutes',
                'total night minutes', 'total intl minutes']

df[num_features].hist(figsize=(10,6), bins=30, edgecolor='black')
plt.suptitle('Distribution of Numerical Features')
plt.show()
```





The histograms for total day minutes, total eve minutes, total night minutes, and total intl minutes show a bell-shaped curve, indicating that these features are normally distributed.

There is no significant skewness in the distributions, meaning the data is fairly balanced.

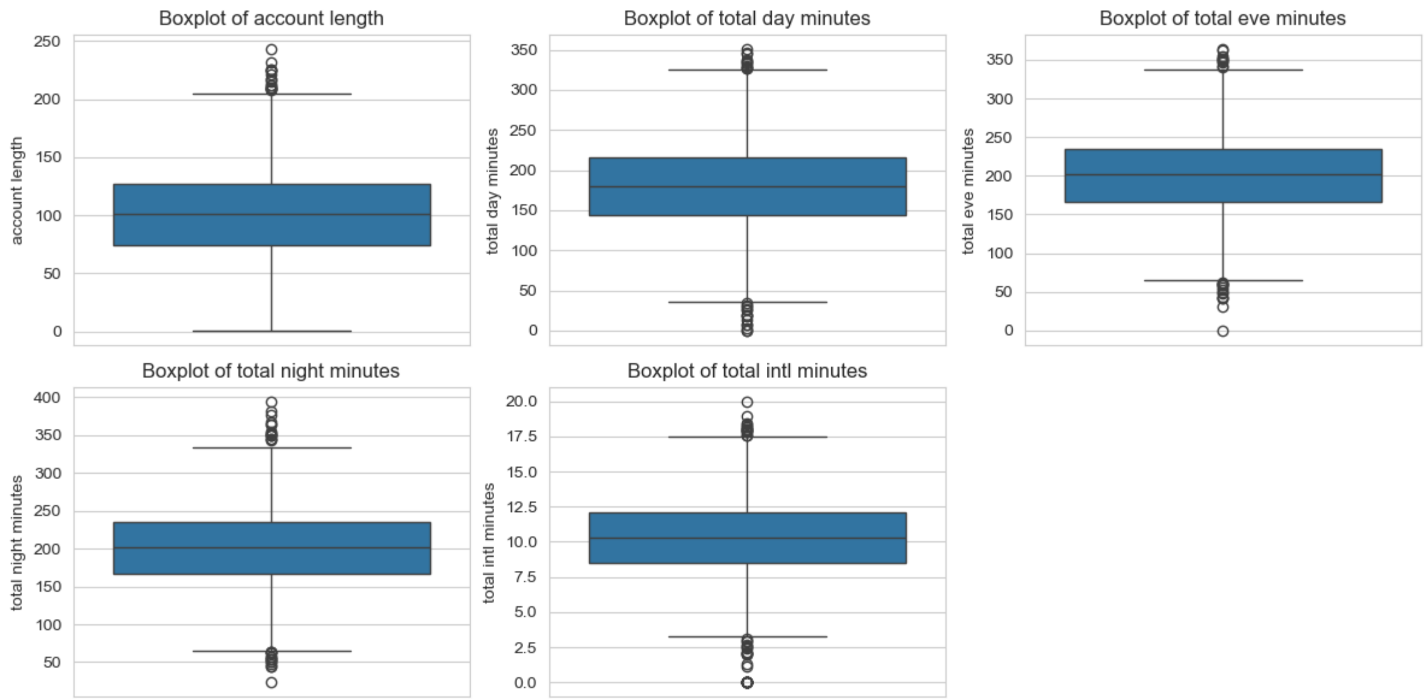
The account length variable also follows a roughly normal distribution, which means customers have a diverse range of account durations.

The distributions do not show extreme values at the tails, meaning there are few or no extreme outliers.

In [385]:

```
# List of numerical columns to check for outliers
numerical_cols = ['account length', 'total day minutes', 'total eve minutes',
                  'total night minutes', 'total intl minutes']

# Create boxplots for each numerical column
plt.figure(figsize=(12, 6))
for i, col in enumerate(numerical_cols, 1):
    plt.subplot(2, 3, i)
    sns.boxplot(y=df[col])
    plt.title(f'Boxplot of {col}')
plt.tight_layout()
plt.show()
```



In [386]:

```
for col in df.columns:
    print(f"Unique values for {col}")
    print(f"N-unique values for {col} is {df[col].nunique()}")
    print(list(df[col].unique()))
    print('-' * 50)
```

```
Unique values for state
N-unique values for state is 51
['KS', 'OH', 'NJ', 'OK', 'AL', 'MA', 'MO', 'LA', 'WV', 'IN', 'RI', 'IA', 'MT', 'NY', 'ID'
, 'VT', 'VA', 'TX', 'FL', 'CO', 'AZ', 'SC', 'NE', 'WY', 'HI', 'IL', 'NH', 'GA', 'AK', 'MD
', 'AR', 'WI', 'OR', 'MI', 'DE', 'UT', 'CA', 'MN', 'SD', 'NC', 'WA', 'NM', 'NV', 'DC', 'K
Y', 'ME', 'MS', 'TN', 'PA', 'CT', 'ND']
--------------------------------------------------
Unique values for account length
N-unique values for account length is 212
[128, 107, 137, 84, 75, 118, 121, 147, 117, 141, 65, 74, 168, 95, 62, 161, 85, 93, 76, 73
, 77, 130, 111, 132, 174, 57, 54, 20, 49, 142, 172, 12, 72, 36, 78, 136, 149, 98, 135, 34
, 160, 64, 59, 119, 97, 52, 60, 10, 96, 87, 81, 68, 125, 116, 38, 40, 43, 113, 126, 150,
138, 162, 90, 50, 82, 144, 46, 70, 55, 106, 94, 155, 80, 104, 99, 120, 108, 122, 157, 103
, 63, 112, 41, 193, 61, 92, 131, 163, 91, 127, 110, 140, 83, 145, 56, 151, 139, 6, 115, 1
46, 185, 148, 32, 25, 179, 67, 19, 170, 164, 51, 208, 53, 105, 66, 86, 35, 88, 123, 45, 1
00, 215, 22, 33, 114, 24, 101, 143, 48, 71, 167, 89, 199, 166, 158, 196, 209, 16, 39, 173
, 129, 44, 79, 31, 124, 37, 159, 194, 154, 21, 133, 224, 58, 11, 109, 102, 165, 18, 30, 1
76, 47, 190, 152, 26, 69, 186, 171, 28, 153, 169, 13, 27, 3, 42, 189, 156, 134, 243, 23,
1, 205, 200, 5, 9, 178, 181, 182, 217, 177, 210, 29, 180, 2, 17, 7, 212, 232, 192, 195, 1
97, 225, 184, 191, 201, 15, 183, 202, 8, 175, 4, 188, 204, 221]
--------------------------------------------------
Unique values for area code
N-unique values for area code is 3
[415, 408, 510]
--------------------------------------------------
Unique values for international plan
N-unique values for international plan is 2
[0, 1]
--------------------------------------------------
Unique values for voice mail plan
N-unique values for voice mail plan is 2
[1, 0]
--------------------------------------------------
Unique values for number vmail messages
N-unique values for number vmail messages is 46
[25, 26, 0, 24, 37, 27, 33, 39, 30, 41, 28, 34, 46, 29, 35, 21, 32, 42, 36, 22, 23, 43, 31
, 38, 40, 48, 18, 17, 45, 16, 20, 14, 19, 51, 15, 11, 12, 47, 8, 44, 49, 4, 10, 13, 50, 9]
--------------------------------------------------
Unique values for total day minutes
N-unique values for total day minutes is 1667
[265.1, 161.6, 243.4, 299.4, 166.7, 223.4, 218.2, 157.0, 184.5, 258.6, 129.1, 187.7, 128
.8, 156.6, 120.7, 332.9, 196.4, 190.7, 189.7, 224.4, 155.1, 62.4, 183.0, 110.4, 81.1, 124
.3, 213.0, 134.3, 190.0, 119.3, 84.8, 226.1, 212.0, 249.6, 176.8, 220.0, 146.3, 130.8, 20
3.9, 140.4, 126.3, 173.1, 124.8, 85.8, 154.0, 120.9, 211.3, 187.0, 159.1, 133.2, 191.9,
220.6, 186.1, 160.2, 151.0, 175.5, 126.9, 198.4, 148.8, 229.3, 192.1, 268.6, 193.7, 180.
7, 131.2, 148.1, 251.5, 125.2, 211.6, 178.9, 241.8, 224.9, 248.6, 203.4, 235.8, 157.1, 3
00.3, 61.6, 214.1, 170.2, 201.1, 215.4, 165.6, 249.5, 210.6, 179.3, 157.9, 214.3, 154.1,
237.9, 143.9, 252.9, 179.1, 278.4, 160.1, 198.2, 212.1, 251.8, 161.2, 178.3, 151.7, 135.
0, 170.5, 238.1, 281.4, 117.9, 148.6, 229.8, 165.0, 185.0, 161.0, 126.7, 58.9, 196.8, 16
2.6, 282.5, 113.7, 239.8, 210.2, 213.8, 170.9, 154.2, 201.4, 70.7, 187.5, 91.7, 214.2, 14
5.5, 166.3, 231.0, 200.3, 197.0, 129.9, 175.8, 203.1, 183.2, 205.0, 148.5, 192.6, 246.5,
167.1, 231.9, 146.7, 271.5, 181.5, 257.7, 193.8, 102.8, 187.9, 226.0, 260.4, 178.7, 337.
4, 157.6, 183.6, 142.1, 136.3, 217.1, 98.9, 206.3, 243.1, 189.8, 202.0, 170.1, 230.9, 23
7.1, 182.1, 116.8, 219.2, 252.6, 147.1, 202.1, 173.5, 232.1, 197.1, 58.2, 115.6, 259.9,
158.7, 271.6, 160.6, 232.4, 133.8, 176.9, 209.9, 137.5, 289.5, 198.1, 149.7, 326.5, 292.
9, 83.0, 145.7, 182.3, 218.0, 140.6, 152.7, 106.7, 243.8, 194.4, 213.9, 217.2, 241.1, 20
3.5, 155.2, 167.6, 226.7, 151.4, 180.0, 250.2, 223.0, 166.0, 136.1, 149.3, 65.4, 213.4,
206.9, 186.2, 280.2, 196.6, 312.0, 199.0, 168.8, 134.4, 202.6, 74.5, 83.6, 192.2, 220.2,
135.1, 253.4, 225.0, 198.5, 110.3, 60.0, 214.8, 181.8, 157.4, 207.9, 207.0, 119.0, 143.7
, 165.9, 138.6, 84.7, 62.6, 164.9, 134.5, 143.3, 168.3, 262.4, 206.2, 225.8, 138.3, 94.4
, 160.0, 206.6, 134.7, 214.4, 192.8, 151.1, 221.4, 218.9, 192.7, 204.4, 172.3, 211.7, 22
1.6, 197.9, 147.5, 206.4, 205.9, 207.6, 303.9, 230.6, 99.5, 177.1, 172.7, 204.2, 85.7, 21
5.5, 171.7, 266.6, 170.4, 158.0, 92.0, 234.0, 272.1, 296.4, 227.2, 248.7, 236.3, 205.6,
94.1, 60.4, 121.0, 117.8, 223.5, 176.3, 138.7, 86.3, 58.8, 68.7, 239.2, 198.3, 205.2, 272
```

.6, 128.3, 169.6, 201.3, 214.7, 169.2, 194.1, 233.8, 225.1, 183.9, 221.8, 64.6, 154.6, 26
0.2, 155.9, 107.0, 182.5, 220.1, 152.2, 236.2, 166.1, 244.6, 134.2, 150.1, 257.1, 124.4,
141.7, 230.0, 162.3, 350.8, 193.3, 78.2, 83.4, 195.6, 201.8, 164.8, 179.2, 214.0, 205.7,
165.5, 221.0, 242.1, 151.6, 176.2, 196.0, 159.5, 230.2, 210.5, 102.0, 126.0, 168.4, 105.
6, 206.5, 229.6, 278.3, 234.4, 167.3, 221.1, 145.8, 222.8, 183.4, 264.3, 146.0, 127.3, 1
78.8, 97.2, 259.8, 256.5, 169.5, 239.7, 171.5, 239.9, 142.3, 184.1, 203.8, 248.8, 192.9,
122.4, 104.9, 173.2, 119.4, 250.3, 155.0, 288.7, 240.4, 190.3, 278.0, 153.5, 273.4, 155.
3, 133.1, 246.8, 165.4, 59.5, 286.7, 117.3, 127.9, 225.5, 149.0, 198.9, 256.4, 264.8, 98
.2, 159.8, 190.6, 184.0, 261.8, 147.9, 106.4, 133.7, 193.5, 178.2, 226.2, 70.9, 240.3, 75
.0, 69.1, 96.6, 214.6, 258.1, 149.8, 190.4, 181.4, 155.7, 149.9, 222.3, 149.4, 242.9, 150
.4, 208.9, 130.7, 119.6, 273.6, 156.1, 177.5, 175.2, 114.3, 251.4, 216.9, 159.3, 143.1,
186.6, 170.8, 124.0, 172.8, 217.4, 265.9, 93.6, 168.2, 202.9, 261.4, 73.3, 253.7, 45.0,
231.3, 47.4, 227.4, 40.9, 68.5, 163.5, 163.0, 213.7, 310.4, 48.4, 171.2, 166.5, 216.6, 10
7.8, 141.3, 237.5, 234.5, 103.1, 129.5, 279.8, 136.8, 100.1, 224.5, 288.1, 148.7, 194.6,
194.5, 174.1, 131.8, 146.8, 200.7, 145.6, 229.4, 211.0, 121.5, 216.0, 293.0, 74.3, 62.3,
228.6, 228.1, 309.9, 201.9, 183.8, 186.7, 209.4, 223.2, 164.2, 150.5, 234.2, 55.3, 89.7,
80.2, 125.7, 207.2, 157.5, 160.4, 159.0, 102.6, 159.7, 202.8, 57.5, 169.9, 335.5, 139.5,
187.8, 146.2, 231.8, 156.4, 220.7, 172.0, 128.2, 130.2, 195.4, 293.3, 191.3, 209.6, 215.
7, 161.4, 144.2, 256.2, 112.7, 299.5, 194.8, 100.8, 82.5, 146.4, 177.9, 150.7, 180.1, 26
5.3, 128.6, 161.5, 165.3, 195.0, 205.5, 235.6, 192.0, 261.7, 235.5, 263.8, 175.6, 242.5,
138.1, 264.7, 282.3, 211.2, 205.3, 252.0, 231.2, 200.1, 266.7, 118.1, 175.3, 125.1, 241.
9, 241.2, 222.4, 189.5, 123.1, 256.7, 30.9, 187.4, 315.6, 277.5, 147.2, 185.8, 155.4, 97
.6, 206.0, 216.8, 103.3, 139.4, 191.2, 221.7, 62.9, 215.6, 94.7, 203.2, 195.3, 114.4, 175
.9, 249.9, 210.7, 87.2, 137.4, 224.8, 261.2, 196.5, 271.2, 300.4, 57.1, 162.1, 145.0, 34.
0, 193.4, 191.7, 161.3, 150.6, 184.6, 121.1, 109.6, 167.5, 115.8, 276.6, 179.4, 187.3, 2
01.2, 189.6, 186.8, 187.6, 244.9, 187.1, 170.7, 161.1, 169.4, 254.4, 127.7, 219.1, 273.5
, 161.9, 241.7, 62.8, 281.1, 228.2, 209.8, 265.6, 214.9, 110.5, 137.8, 112.8, 180.4, 153
.7, 261.3, 246.2, 191.0, 208.3, 253.0, 202.3, 174.4, 127.1, 143.5, 186.9, 194.0, 234.8,
123.7, 173.9, 130.9, 314.6, 227.9, 95.5, 185.3, 105.8, 178.0, 172.1, 169.3, 119.1, 194.2
, 198.8, 167.7, 202.2, 322.5, 216.2, 76.4, 72.7, 210.4, 127.2, 219.5, 99.3, 224.7, 176.6
, 283.9, 180.6, 125.9, 237.6, 274.3, 199.6, 217.7, 212.7, 256.3, 267.9, 163.6, 180.9, 10
5.0, 271.4, 206.7, 166.8, 204.9, 127.0, 267.4, 281.0, 270.8, 124.1, 162.8, 254.8, 254.9,
107.7, 158.8, 182.9, 178.4, 110.9, 166.9, 244.8, 120.8, 215.9, 140.1, 139.8, 321.6, 166.
6, 260.0, 190.2, 82.2, 163.8, 267.8, 287.3, 101.2, 109.1, 110.1, 111.0, 144.8, 135.4, 84
.2, 209.1, 130.1, 136.7, 67.7, 200.4, 125.8, 226.3, 120.5, 91.1, 167.9, 257.4, 237.2, 103
.0, 153.8, 205.1, 175.7, 154.4, 209.7, 150.0, 199.2, 217.6, 175.4, 152.0, 174.9, 176.4,
160.9, 228.7, 144.0, 135.9, 334.3, 130.5, 105.4, 188.9, 111.8, 212.4, 346.8, 113.9, 171.
4, 275.4, 197.2, 116.1, 217.3, 207.7, 277.3, 125.3, 216.7, 97.4, 246.4, 143.4, 156.2, 11
4.8, 232.5, 143.6, 176.7, 263.4, 167.8, 142.5, 133.0, 95.0, 198.6, 142.6, 111.9, 122.8,
189.3, 93.5, 158.6, 243.2, 220.9, 144.4, 212.3, 147.0, 96.2, 12.5, 178.1, 123.0, 208.0,
193.0, 174.5, 116.7, 93.8, 239.5, 167.4, 143.2, 232.8, 162.0, 25.9, 322.3, 191.5, 291.1,
208.8, 255.9, 252.7, 132.1, 217.0, 101.9, 211.5, 153.4, 185.2, 104.6, 245.2, 274.4, 98.4
, 279.9, 187.2, 276.2, 217.8, 190.5, 179.9, 235.9, 144.6, 189.0, 101.0, 165.1, 189.1, 13
1.5, 166.4, 87.7, 35.1, 246.6, 78.5, 251.6, 270.3, 177.3, 262.2, 173.6, 106.6, 209.5, 95.
4, 131.6, 112.2, 172.5, 194.3, 307.1, 118.2, 155.5, 125.6, 199.3, 222.2, 92.8, 193.2, 11
3.2, 166.2, 207.8, 245.4, 287.1, 192.3, 141.9, 220.5, 156.0, 235.1, 188.4, 247.8, 221.2,
118.5, 83.5, 183.3, 236.8, 134.0, 191.4, 174.8, 275.2, 174.0, 107.9, 221.3, 141.1, 178.6
, 139.0, 181.6, 84.9, 217.9, 270.9, 243.0, 150.9, 219.9, 168.0, 256.8, 182.8, 117.6, 145
.4, 169.1, 186.4, 76.1, 260.8, 211.8, 162.7, 121.7, 67.4, 229.7, 176.0, 247.7, 115.4, 139
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Unique values for total eve calls
N-unique values for total eve calls is 123
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Unique values for total eve charge
N-unique values for total eve charge is 1440
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Unique values for total night minutes

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N-unique values for total night minutes is 1591
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72, 4.64, 8.96, 13.03, 6.07, 3.51, 6.83, 6.12, 9.31, 9.58, 4.68, 5.32, 9.26, 11.52, 9.11,
10.55, 11.47, 9.3, 13.82, 8.44, 5.77, 10.96, 11.74, 8.9, 10.47, 7.85, 10.92, 4.74, 9.74,
10.43, 9.96, 10.18, 9.54, 7.89, 12.36, 8.54, 10.07, 9.46, 7.3, 11.16, 9.16, 10.19, 5.99,
10.88, 5.8, 7.19, 4.55, 8.31, 8.01, 14.43, 8.3, 14.3, 6.53, 8.2, 11.31, 13.0, 6.42, 4.24,
7.44, 7.51, 13.1, 9.49, 6.14, 8.76, 6.65, 10.56, 6.72, 8.29, 12.09, 5.39, 2.96, 7.59, 7.2
4, 4.28, 9.7, 8.83, 13.3, 11.37, 9.33, 5.01, 3.26, 11.71, 8.43, 9.68, 15.56, 9.8, 3.61, 6
.96, 11.61, 12.81, 10.87, 13.84, 5.03, 5.17, 2.03, 10.34, 9.34, 7.95, 10.09, 9.95, 7.11,
9.22, 6.13, 11.05, 9.89, 9.39, 14.06, 10.26, 13.31, 15.43, 16.39, 6.27, 10.64, 11.5, 12.4
8, 8.27, 13.53, 10.36, 12.24, 8.69, 10.52, 9.07, 11.51, 9.25, 8.72, 6.78, 8.6, 11.84, 5.7
8, 5.85, 12.3, 5.76, 12.07, 9.6, 8.84, 12.39, 10.1, 9.73, 2.85, 6.66, 2.45, 5.28, 11.73,
10.75, 7.74, 6.76, 6.0, 7.58, 13.69, 7.93, 7.68, 9.75, 4.96, 5.49, 11.83, 7.18, 9.19, 7.7
, 7.25, 10.74, 4.27, 13.8, 9.12, 4.75, 7.78, 11.63, 7.55, 2.25, 9.45, 9.86, 7.71, 4.95, 7
.4, 11.17, 11.33, 6.82, 13.7, 1.97, 10.89, 12.77, 10.31, 5.23, 5.27, 9.41, 6.09, 10.61, 7
.29, 4.23, 7.57, 3.67, 12.69, 14.5, 5.95, 7.87, 5.96, 5.94, 12.23, 4.9, 12.33, 6.89, 9.67
, 12.68, 12.87, 3.7, 6.04, 13.13, 15.74, 11.87, 4.7, 4.67, 7.05, 5.42, 4.09, 5.73, 9.47,
8.05, 6.87, 3.71, 15.86, 7.49, 11.69, 6.46, 10.45, 12.9, 5.41, 11.26, 1.04, 6.49, 6.37, 1
2.21, 6.77, 12.65, 7.86, 9.44, 4.3, 7.38, 5.02, 10.63, 2.86, 17.19, 8.67, 8.37, 6.9, 10.9
3, 10.38, 7.36, 10.27, 10.95, 6.11, 4.45, 11.9, 15.01, 12.84, 7.45, 6.98, 11.72, 7.56, 11
.38, 10.0, 4.42, 9.81, 5.56, 6.01, 10.12, 12.4, 16.99, 5.68, 11.64, 3.78, 7.82, 9.85, 13.
74, 12.71, 10.98, 10.01, 9.52, 7.31, 8.35, 11.35, 9.5, 14.03, 3.2, 7.72, 13.22, 10.7, 8.9
9, 10.6, 13.02, 9.77, 12.58, 12.35, 12.2, 11.4, 13.91, 3.57, 14.65, 12.28, 5.13, 10.72,
12.86, 14.0, 7.12, 12.17, 4.71, 6.28, 8.0, 7.01, 5.91, 5.2, 12.0, 12.02, 12.88, 7.28, 5.4
, 12.04, 5.24, 10.3, 10.41, 13.41, 12.72, 9.08, 7.08, 13.5, 5.35, 12.45, 5.3, 10.32, 5.15
, 12.67, 5.22, 5.57, 3.94, 4.41, 13.27, 10.24, 4.25, 12.89, 5.72, 12.5, 11.29, 3.25, 11.5
3, 9.82, 7.26, 4.1, 10.37, 4.98, 6.74, 12.52, 14.56, 8.34, 3.82, 3.86, 13.97, 11.57, 6.5,
13.58, 14.32, 13.75, 11.14, 14.18, 9.13, 4.46, 4.83, 9.69, 14.13, 7.16, 7.98, 13.66, 14.7
8, 11.2, 9.93, 11.0, 5.29, 9.92, 4.29, 11.1, 10.51, 12.49, 4.04, 12.94, 7.09, 6.71, 7.94,
5.31, 5.98, 7.2, 14.82, 13.21, 12.32, 10.58, 4.92, 6.2, 4.47, 11.98, 6.18, 7.81, 4.54, 5.
37, 7.17, 5.33, 14.1, 5.7, 12.18, 8.98, 5.1, 14.67, 13.95, 16.55, 11.18, 4.44, 4.73, 2.55
, 6.31, 2.43, 9.24, 7.37, 13.42, 12.42, 11.8, 14.45, 2.89, 13.23, 12.6, 13.18, 12.19, 14.
81, 6.55, 11.3, 12.27, 13.98, 8.23, 15.49, 6.47, 13.48, 13.59, 13.25, 17.77, 13.9, 3.97,
11.56, 14.08, 13.6, 6.26, 4.61, 12.76, 15.76, 6.38, 3.6, 12.8, 5.9, 7.97, 5.0, 10.97, 5.8
8, 12.34, 12.03, 14.97, 15.06, 12.85, 6.54, 11.24, 12.64, 7.06, 5.38, 13.14, 3.99, 3.32,
4.51, 4.12, 3.93, 2.4, 11.75, 4.03, 15.85, 6.81, 14.25, 14.09, 16.42, 6.7, 12.74, 2.76, 1
2.12, 6.99, 6.68, 11.81, 7.96, 5.06, 13.16, 2.13, 13.17, 5.12, 5.65, 12.37, 10.53]
-------------------------------------------------------
Unique values for total intl minutes
N-unique values for total intl minutes is 162
[10.0, 13.7, 12.2, 6.6, 10.1, 6.3, 7.5, 7.1, 8.7, 11.2, 12.7, 9.1, 12.3, 13.1, 5.4, 13.8,
8.1, 13.0, 10.6, 5.7, 9.5, 7.7, 10.3, 15.5, 14.7, 11.1, 14.2, 12.6, 11.8, 8.3, 14.5, 10.5
, 9.4, 14.6, 9.2, 3.5, 8.5, 13.2, 7.4, 8.8, 11.0, 7.8, 6.8, 11.4, 9.3, 9.7, 10.2, 8.0, 5.
8, 12.1, 12.0, 11.6, 8.2, 6.2, 7.3, 6.1, 11.7, 15.0, 9.8, 12.4, 8.6, 10.9, 13.9, 8.9, 7.9
, 5.3, 4.4, 12.5, 11.3, 9.0, 9.6, 13.3, 20.0, 7.2, 6.4, 14.1, 14.3, 6.9, 11.5, 15.8, 12.8
, 16.2, 0.0, 11.9, 9.9, 8.4, 10.8, 13.4, 10.7, 17.6, 4.7, 2.7, 13.5, 12.9, 14.4, 10.4, 6.
7, 15.4, 4.5, 6.5, 15.6, 5.9, 18.9, 7.6, 5.0, 7.0, 14.0, 18.0, 16.0, 14.8, 3.7, 2.0, 4.8,
```

```
15.3, 6.0, 13.6, 17.2, 17.5, 5.6, 18.2, 3.6, 16.5, 4.6, 5.1, 4.1, 16.3, 14.9, 16.4, 16.7,
1.3, 15.2, 15.1, 15.9, 5.5, 16.1, 4.0, 16.9, 5.2, 4.2, 15.7, 17.0, 3.9, 3.8, 2.2, 17.1, 4
.9, 17.9, 17.3, 18.4, 17.8, 4.3, 2.9, 3.1, 3.3, 2.6, 3.4, 1.1, 18.3, 16.6, 2.1, 2.4, 2.5]
--------------------------------------------------
Unique values for total intl calls
N-unique values for total intl calls is 21
[3, 5, 7, 6, 4, 2, 9, 19, 1, 10, 15, 8, 11, 0, 12, 13, 18, 14, 16, 20, 17]
--------------------------------------------------
Unique values for total intl charge
N-unique values for total intl charge is 162
[2.7, 3.7, 3.29, 1.78, 2.73, 1.7, 2.03, 1.92, 2.35, 3.02, 3.43, 2.46, 3.32, 3.54, 1.46, 3
.73, 2.19, 3.51, 2.86, 1.54, 2.57, 2.08, 2.78, 4.19, 3.97, 3.0, 3.83, 3.4, 3.19, 2.24, 3.
92, 2.84, 2.54, 3.94, 2.48, 0.95, 2.3, 3.56, 2.0, 2.38, 2.97, 2.11, 1.84, 3.08, 2.51, 2.6
2, 2.75, 2.16, 1.57, 3.27, 3.24, 3.13, 2.21, 1.67, 1.97, 1.65, 3.16, 4.05, 2.65, 3.35, 2.
32, 2.94, 3.75, 2.4, 2.13, 1.43, 1.19, 3.38, 3.05, 2.43, 2.59, 3.59, 5.4, 1.94, 1.73, 3.8
1, 3.86, 1.86, 3.11, 4.27, 3.46, 4.37, 0.0, 3.21, 2.67, 2.27, 2.92, 3.62, 2.89, 4.75, 1.2
7, 0.73, 3.65, 3.48, 3.89, 2.81, 1.81, 4.16, 1.22, 1.76, 4.21, 1.59, 5.1, 2.05, 1.35, 1.8
9, 3.78, 4.86, 4.32, 4.0, 1.0, 0.54, 1.3, 4.13, 1.62, 3.67, 4.64, 4.73, 1.51, 4.91, 0.97,
4.46, 1.24, 1.38, 1.11, 4.4, 4.02, 4.43, 4.51, 0.35, 4.1, 4.08, 4.29, 1.49, 4.35, 1.08, 4
.56, 1.4, 1.13, 4.24, 4.59, 1.05, 1.03, 0.59, 4.62, 1.32, 4.83, 4.67, 4.97, 4.81, 1.16, 0
.78, 0.84, 0.89, 0.7, 0.92, 0.3, 4.94, 4.48, 0.57, 0.65, 0.68]
--------------------------------------------------
Unique values for customer service calls
N-unique values for customer service calls is 10
[1, 0, 2, 3, 4, 5, 7, 9, 6, 8]
--------------------------------------------------
Unique values for churn
N-unique values for churn is 2
[False, True]
--------------------------------------------------
```

Feature Engineering

In [387]:

```
#Creating total calls, total minutes and total charge

df['total calls'] = df['total day calls'] + df['total eve calls'] + df['total night call
s'] + df['total intl calls']
df['total minutes'] = df['total day minutes'] + df['total eve minutes'] + df['total nigh
t minutes'] + df['total intl minutes']
df['total charge'] = df['total day charge'] + df['total eve charge'] + df['total night c
harge'] + df['total intl charge']

df.head()
```

Out[387]:

	state	account length	area code	international plan	voice mail plan	number vmail messages	total day minutes	total day calls	total day charge	total eve minutes	...	total night calls	total night charge	total intl minutes	total intl calls	ch
0	KS	128	415	0	1	25	265.1	110	45.07	197.4	...	91	11.01	10.0	3	
1	OH	107	415	0	1	26	161.6	123	27.47	195.5	...	103	11.45	13.7	3	
2	NJ	137	415	0	0	0	243.4	114	41.38	121.2	...	104	7.32	12.2	5	
3	OH	84	408	1	0	0	299.4	71	50.90	61.9	...	89	8.86	6.6	7	
4	OK	75	415	1	0	0	166.7	113	28.34	148.3	...	121	8.41	10.1	3	

5 rows × 23 columns

Churn rate by plan

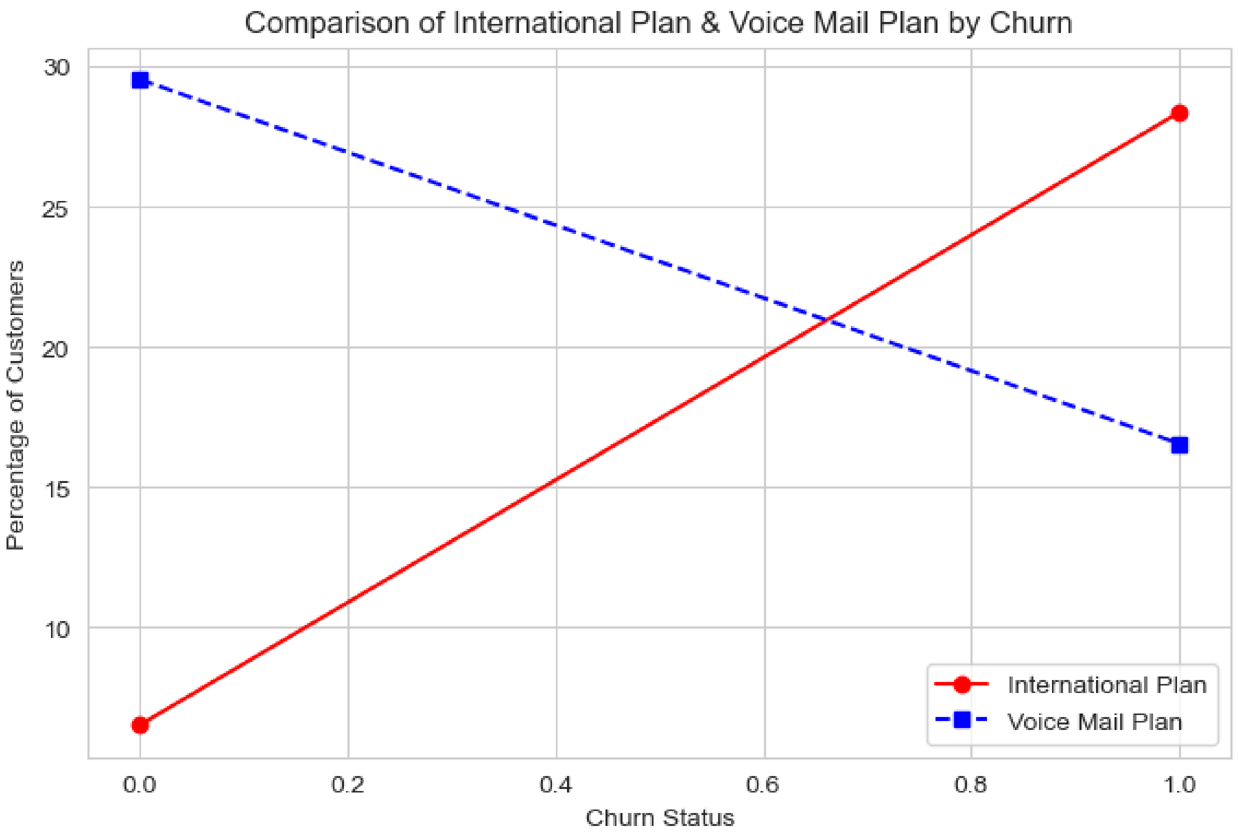
In [388]:

```
# Calculate percentage of customers with International Plan and Voice Mail Plan by Churn
```

```
status
churn_group = df.groupby("churn")[["international plan", "voice mail plan"]].mean() * 10
0

# Plot the line graph
plt.figure(figsize=(8, 5))
plt.plot(churn_group.index, churn_group["international plan"], marker='o', linestyle='-'
, label="International Plan", color='red')
plt.plot(churn_group.index, churn_group["voice mail plan"], marker='s', linestyle='--',
label="Voice Mail Plan", color='blue')

# Graph formatting
plt.title("Comparison of International Plan & Voice Mail Plan by Churn")
plt.xlabel("Churn Status")
plt.ylabel("Percentage of Customers")
plt.legend()
plt.grid(True)
plt.show()
```



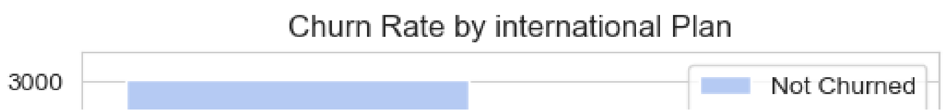
International Plan: The line shows that customers with an international plan have a significantly higher churn rate. The percentage of customers with an international plan who churn (churn status = 1) is much higher than those who don't churn (churn status = 0).

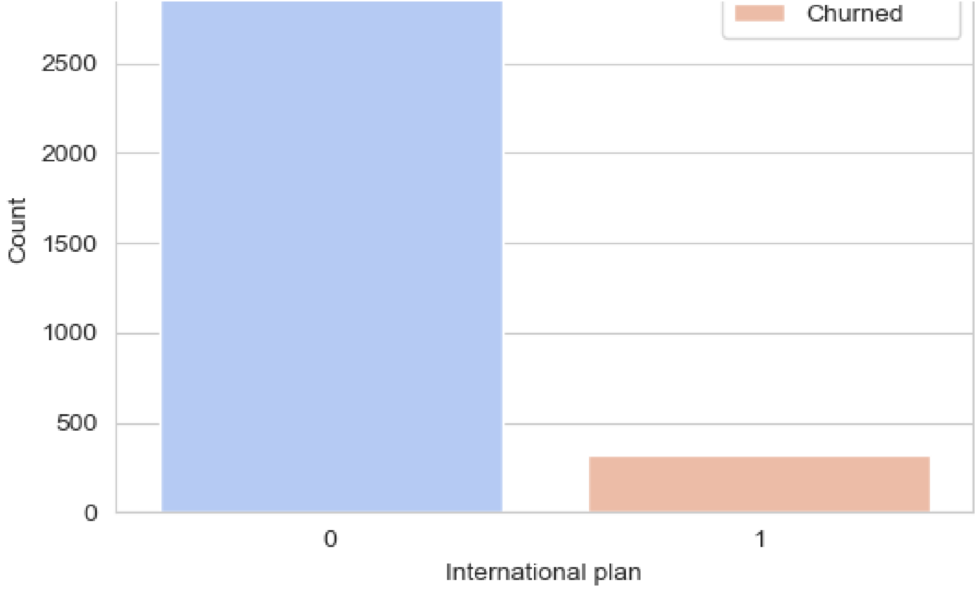
Voice Mail Plan: The line indicates that customers with a voice mail plan have a lower churn rate. The percentage of customers with a voice mail plan who churn is lower than those who don't.

International plan vs Churn rate

In [389]:

```
plt.figure(figsize=(6, 4))
sns.countplot(x="international plan", data=df, palette="coolwarm")
plt.title("Churn Rate by international Plan")
plt.xlabel("International plan")
plt.ylabel("Count")
plt.legend(["Not Churned", "Churned"])
plt.show()
```

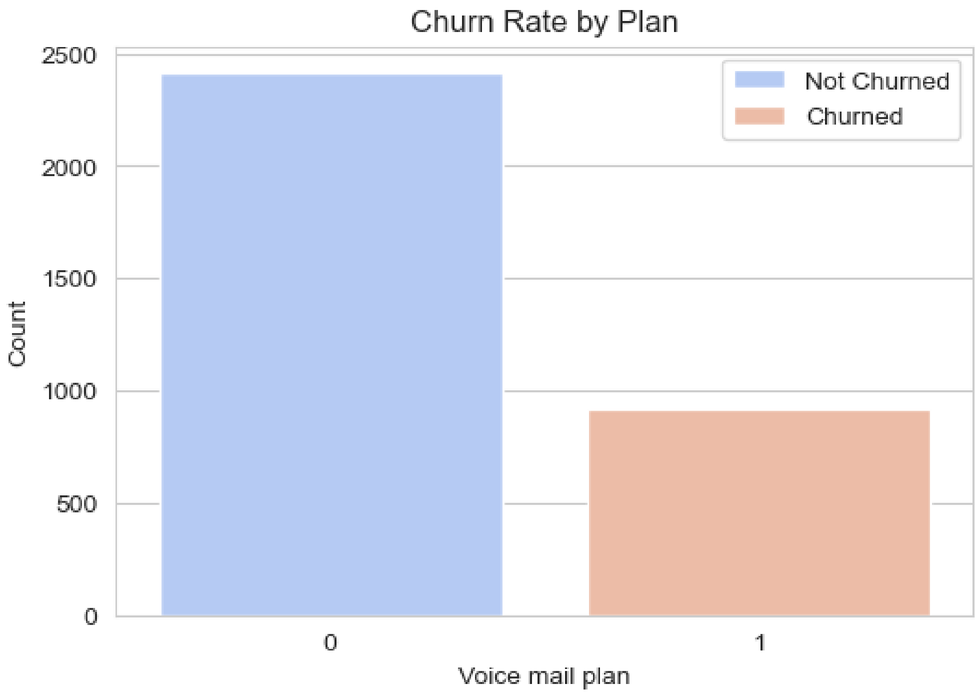




Voice mail plan vs Churn rate

In [390]:

```
plt.figure(figsize=(6, 4))
sns.countplot(x="voice mail plan", data=df, palette="coolwarm")
plt.title("Churn Rate by Plan")
plt.xlabel("Voice mail plan")
plt.ylabel("Count")
plt.legend(["Not Churned", "Churned"])
plt.show()
```



Churn rate by state

To identify which regions have the highest churn rate

In [391]:

```
# Grouping data by state and calculate churn rate
churn_by_state = df.groupby("state")["churn"].mean().reset_index()

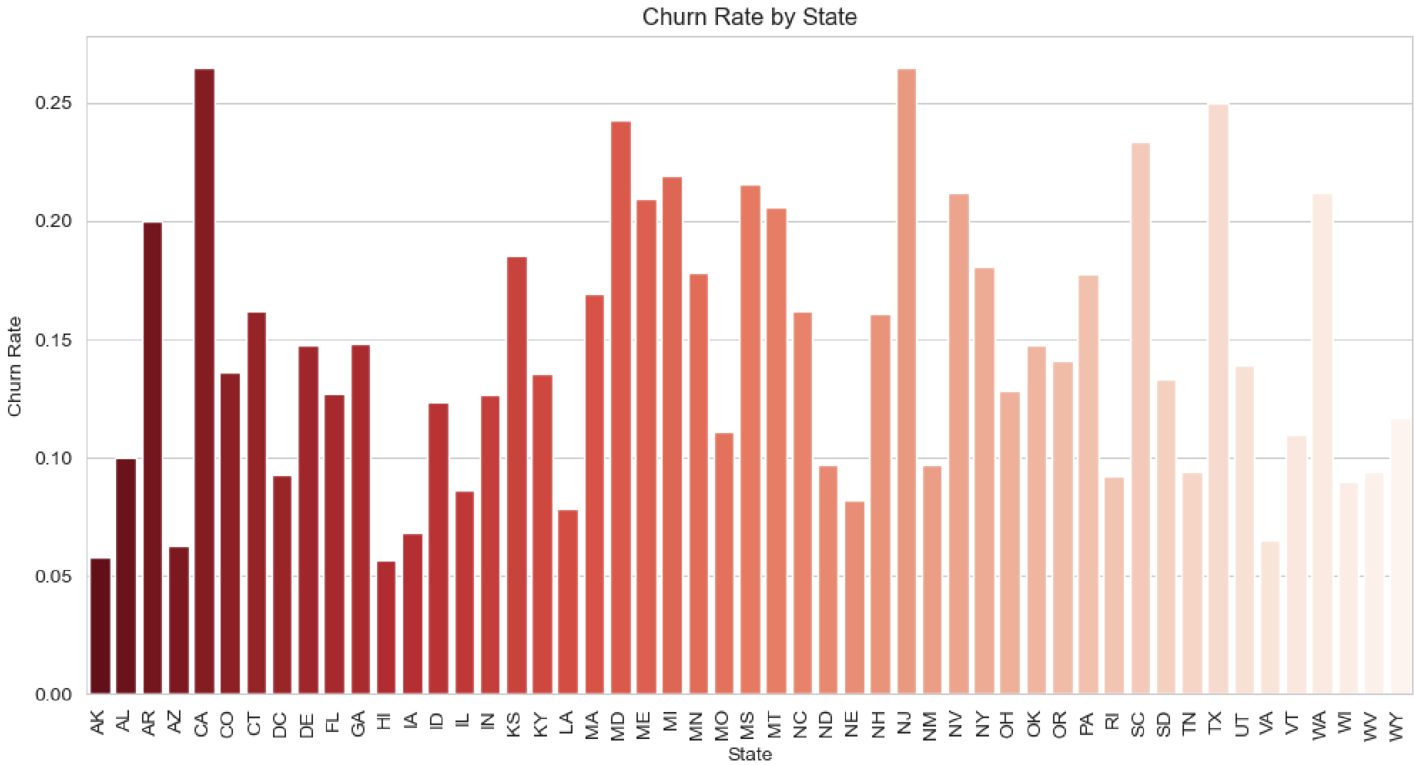
# Sorting by churn rate in descending order
churn_by_state = churn_by_state.sort_values(by="churn", ascending=False)

# Rename column for better readability
```

```
churn_by_state.columns = ["State", "Churn Rate"]

# Plotting churn rate by state
plt.figure(figsize=(12,6))
sns.barplot(x="State", y="Churn Rate", data=churn_by_state, palette="Reds_r")
plt.xticks(rotation=90)
plt.title("Churn Rate by State")
plt.xlabel("State")
plt.ylabel("Churn Rate")
plt.show()

# Display top 10 states with highest churn rate
print("\nTop 10 States with Highest Churn Rate:")
print(churn_by_state.head(10))
```




```
Top 10 States with Highest Churn Rate:
   State  Churn Rate
31    NJ    0.264706
4     CA    0.264706
43    TX    0.250000
20    MD    0.242857
40    SC    0.233333
22    MI    0.219178
25    MS    0.215385
33    NV    0.212121
47    WA    0.212121
21    ME    0.209677
```

New Jersey (NJ) and California (CA) have the highest churn rate (26.47%)

Texas (TX), Maryland (MD), and South Carolina (SC) also show high churn (23-25%)

Michigan (MI), Mississippi (MS), Nevada (NV), Washington (WA), and Maine (ME) have churn rates around 21%

These states are still above average in churn but not as critical as NJ and CA.

Customer service calls vs. churn, to see if more complaints affect churn.

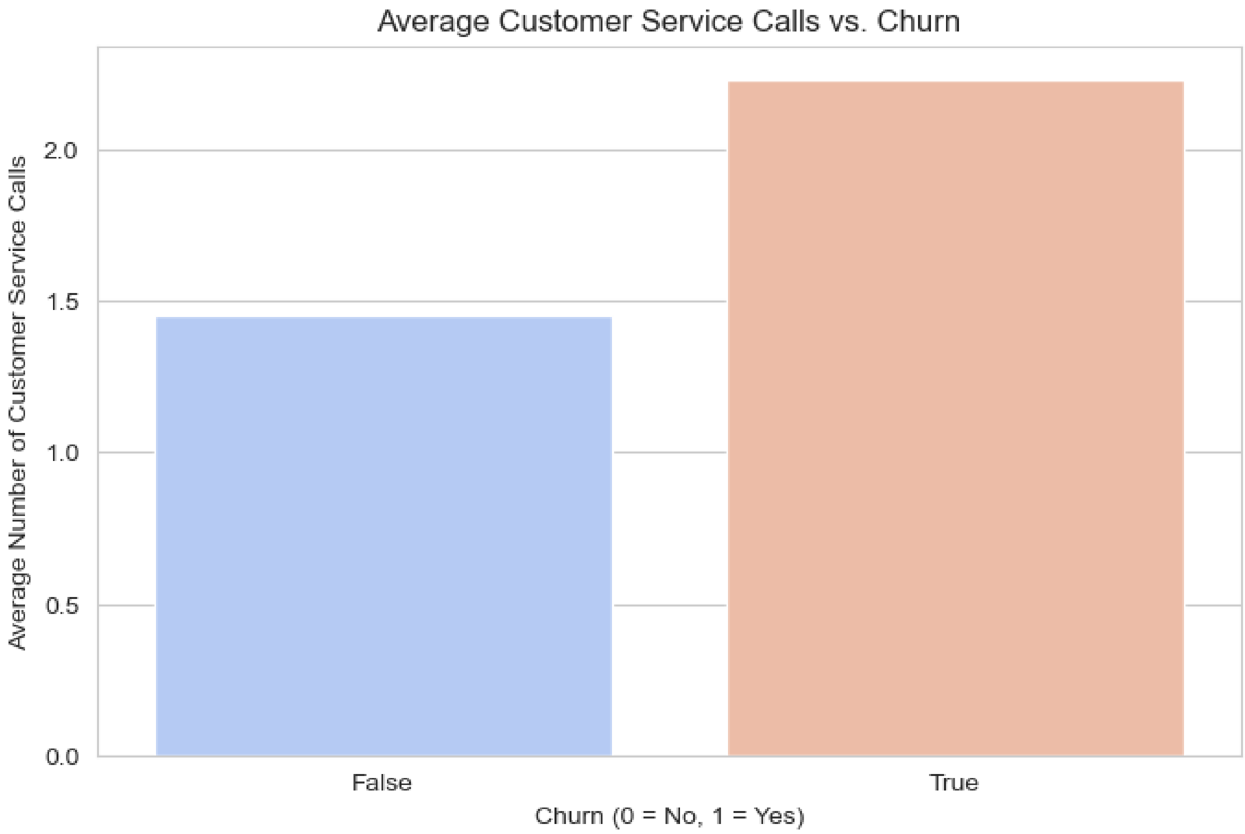
In [392]:

```
plt.figure(figsize=(8, 5))
sns.barplot(data=df, x='churn', y='customer service calls', palette='coolwarm', ci=None)

plt.title('Average Customer Service Calls vs. Churn')
```

```
plt.xlabel('Churn (0 = No, 1 = Yes)')
plt.ylabel('Average Number of Customer Service Calls')

plt.show()
```



Churned Customers Call More:

The bar for True (Churned Customers) is higher than the bar for False (Non-Churned Customers).

Churned customers make around 2+ service calls, whereas non-churned customers average around 1.5 calls. This suggests that higher service call frequency might indicate customer dissatisfaction, leading to churn.

Distribution of total day minutes for churned vs. non-churned customers.

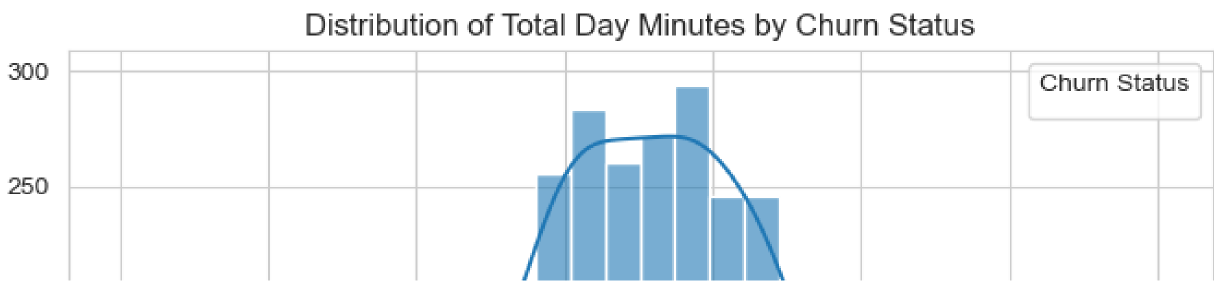
In [393]:

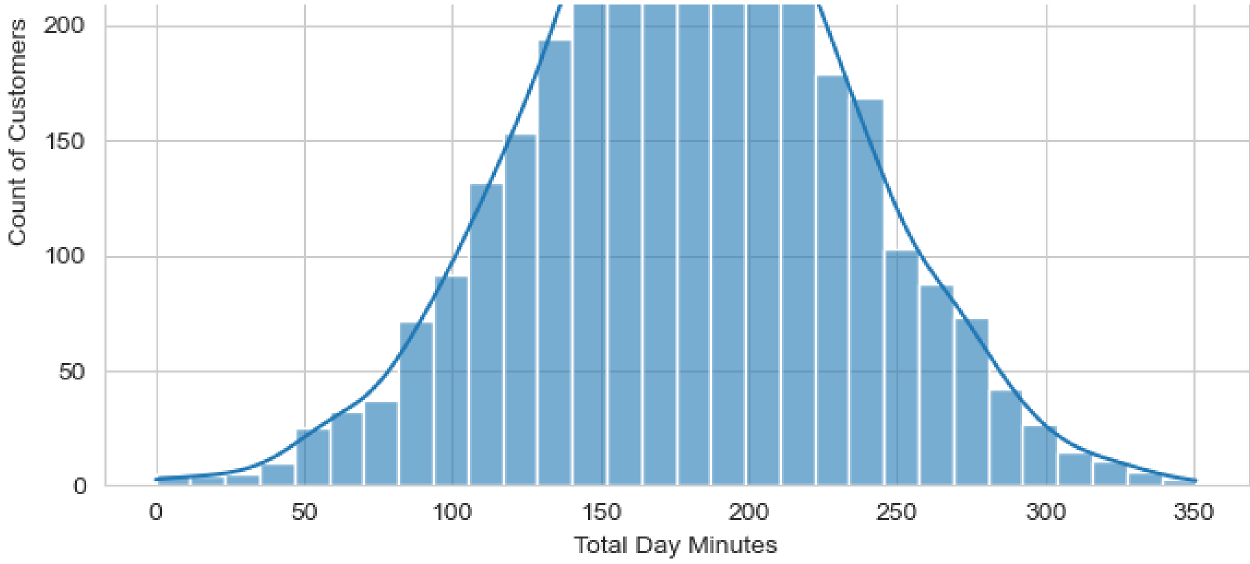
```
# Plot the distribution of total day minutes for churned vs. non-churned customers
plt.figure(figsize=(8, 5))
sns.histplot(data=df, x="total day minutes", kde=True, bins=30, palette="coolwarm", alph
a=0.6)

# Formatting
plt.title("Distribution of Total Day Minutes by Churn Status")
plt.xlabel("Total Day Minutes")
plt.ylabel("Count of Customers")
plt.legend(title="Churn Status")

# Show the plot
plt.show()
```

```
No artists with labels found to put in legend.  Note that artists whose label start with
an underscore are ignored when legend() is called with no argument.
```





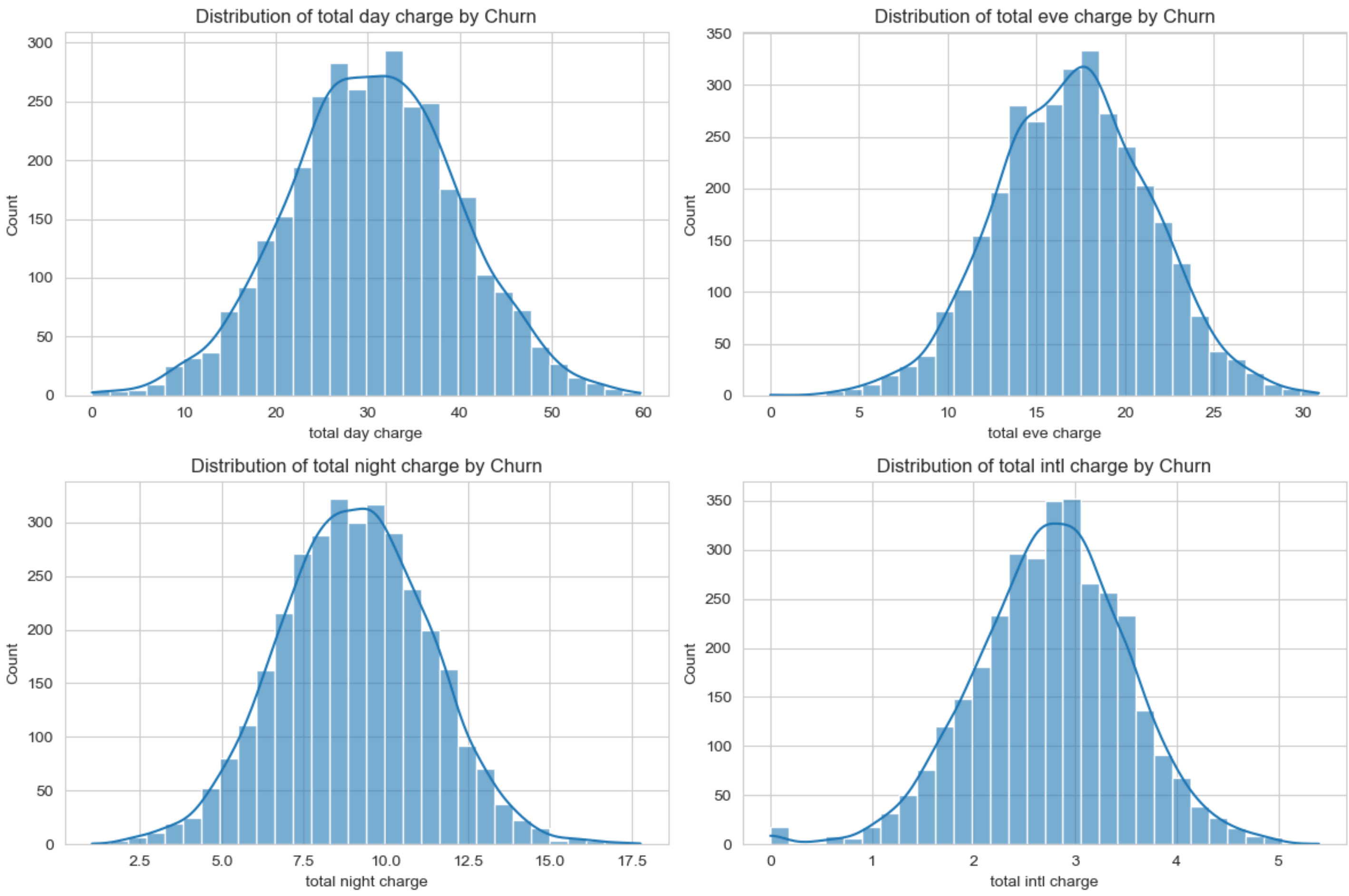
Total charge vs Churn

In [394]:

```
# Define charge columns
charge_columns = ["total day charge", "total eve charge", "total night charge", "total in
tl charge"]

# Plot distribution for each charge category
plt.figure(figsize=(12, 8))
for i, col in enumerate(charge_columns, 1):
    plt.subplot(2, 2, i)
    sns.histplot(data=df, x=col, kde=True, bins=30, palette="coolwarm", alpha=0.6)
    plt.title(f"Distribution of {col} by Churn")
    plt.xlabel(col)
    plt.ylabel("Count")

plt.tight_layout()
plt.show()
```



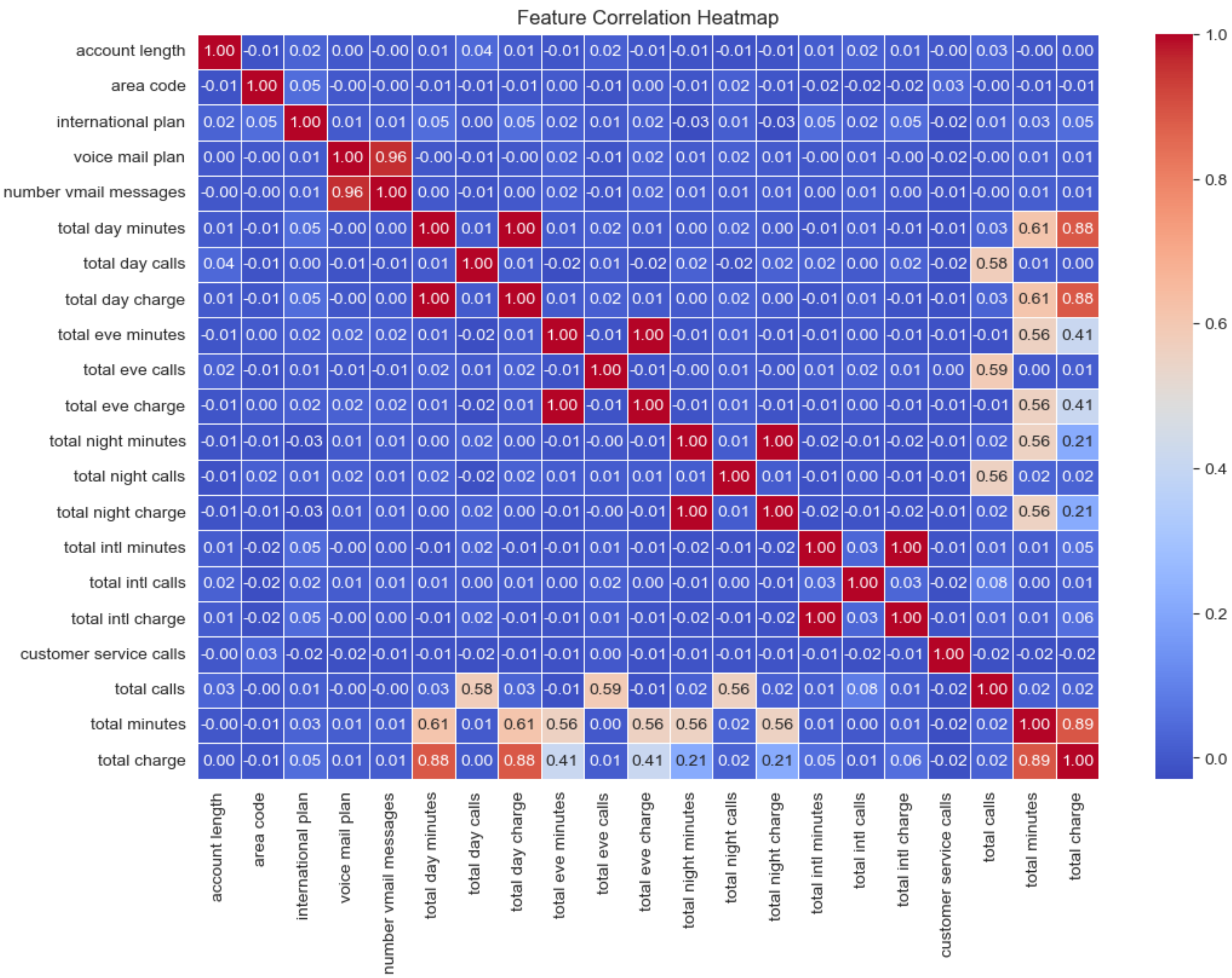
Correlation heatmap.

In [395]:

```
# Drop categorical columns
df_numeric = df.select_dtypes(include=['number'])

# Computing correlation matrix
plt.figure(figsize=(12, 8))
corr_matrix = df_numeric.corr()

# Heatmap
sns.heatmap(corr_matrix, annot=True, fmt=".2f", cmap="coolwarm", linewidths=0.5)
plt.title("Feature Correlation Heatmap")
plt.show()
```



Encoding Categorical variables

In [396]:

```
# Converting state to numerical using One-Hot Encoding
df_encoded = pd.get_dummies(df, columns=['state'], drop_first=True)
```

Scaling numerical features

In [397]:

```
# Define numerical features to scale
num_features = ['account length', 'total day minutes', 'total day calls', 'total day char
ge',
                'total eve minutes', 'total eve calls', 'total eve charge',
                'total night minutes', 'total night calls', 'total night charge',
```

```
                 'total intl minutes', 'total intl calls', 'total intl charge', 'customer
service calls']

# Apply StandardScaler
scaler = StandardScaler()
df_encoded[num_features] = scaler.fit_transform(df_encoded[num_features])
```

Modeling

In [398]:

```
from sklearn.linear_model import LinearRegression
from sklearn.model_selection import train_test_split
from sklearn.metrics import mean_squared_error, r2_score

# Selecting Features (X) and Target Variable (y)
X = df[['total day minutes']]
y = df['total charge']

# Train-Test Split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42
)

# Train Linear Regression Model
lin_reg = LinearRegression()
lin_reg.fit(X_train, y_train)

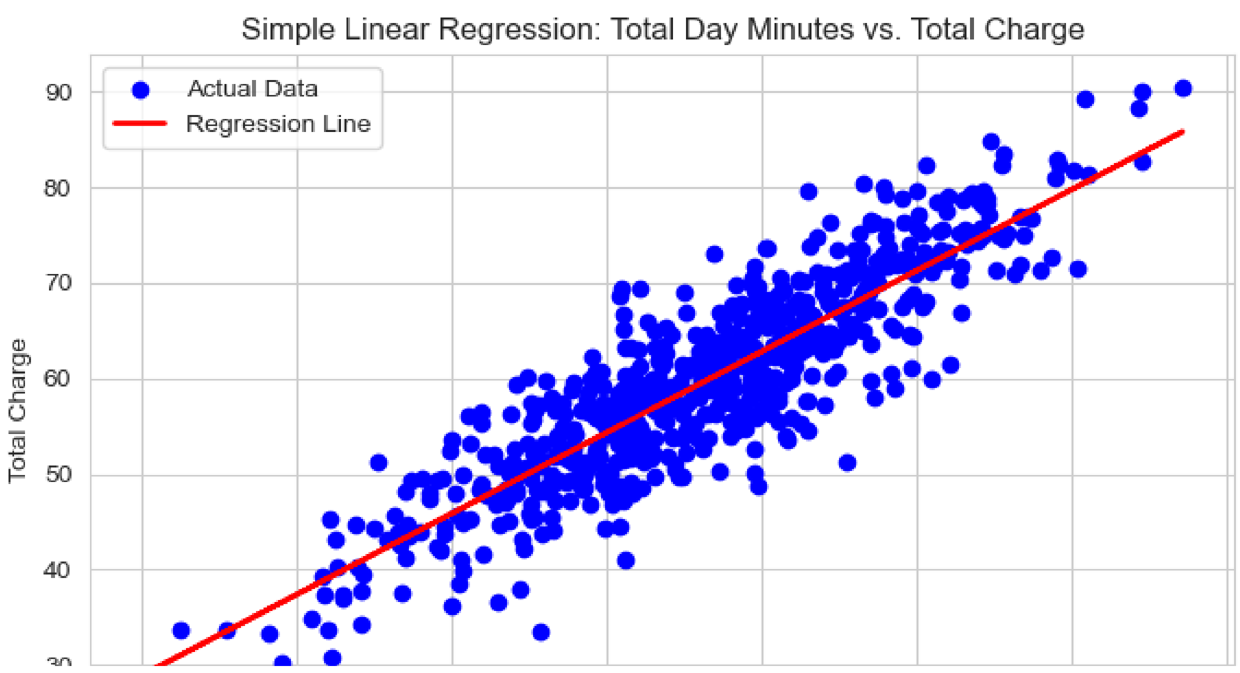
# Predictions
y_pred = lin_reg.predict(X_test)

# Model Performance
print(f"R² Score: {r2_score(y_test, y_pred):.4f}")
print(f"Mean Squared Error: {mean_squared_error(y_test, y_pred):.4f}")

# Plot the Regression Line
import matplotlib.pyplot as plt

plt.figure(figsize=(8, 5))
plt.scatter(X_test, y_test, color="blue", label="Actual Data")
plt.plot(X_test, y_pred, color="red", linewidth=2, label="Regression Line")
plt.xlabel("Total Day Minutes")
plt.ylabel("Total Charge")
plt.title("Simple Linear Regression: Total Day Minutes vs. Total Charge")
plt.legend()
plt.show()
```

```
R² Score: 0.7959
Mean Squared Error: 23.5925
```



In [399]:

```
import statsmodels.api as sm

# Selecting Features (X) and Target Variable (y)
X = df[['total day minutes']]
y = df['total charge']

# Add constant term (intercept)
X = sm.add_constant(X)

# Fit the OLS model
model = sm.OLS(y, X).fit()

# Print summary
print(model.summary())
```

```
                            OLS Regression Results
==============================================================================
Dep. Variable:           total charge   R-squared:                       0.783
Model:                            OLS   Adj. R-squared:                  0.783
Method:                 Least Squares   F-statistic:                 1.200e+04
Date:                Sun, 09 Mar 2025   Prob (F-statistic):               0.00
Time:                        15:55:15   Log-Likelihood:                -10022.
No. Observations:                3333   AIC:                         2.005e+04
Df Residuals:                    3331   BIC:                         2.006e+04
Df Model:                           1
Covariance Type:            nonrobust
=====================================================================================
                        coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------------
const                28.7809      0.292     98.403      0.000      28.207      29.354
total day minutes     0.1706      0.002    109.564      0.000       0.168       0.174
==============================================================================
Omnibus:                        3.536   Durbin-Watson:                   1.987
Prob(Omnibus):                  0.171   Jarque-Bera (JB):                3.583
Skew:                          -0.076   Prob(JB):                        0.167
Kurtosis:                       2.950   Cond. No.                         648.
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifie
d.
```

Multiple linear regression

In [400]:

```
# Selecting Features
X_multi = df[['total day minutes', 'total eve minutes', 'total night minutes', 'total in
tl minutes']]
y_multi = df['total charge']

# Train-Test Split
X_train_m, X_test_m, y_train_m, y_test_m = train_test_split(X_multi, y_multi, test_size=
0.2, random_state=42)

# Train the Model
multi_reg = LinearRegression()
multi_reg.fit(X_train_m, y_train_m)

# Predictions
y_pred_m = multi_reg.predict(X_test_m)
```

```python
# Model Performance
print(f"R² Score: {r2_score(y_test_m, y_pred_m):.4f}")
print(f"Mean Squared Error: {mean_squared_error(y_test_m, y_pred_m):.4f}")

# Print Coefficients
coef_dict = dict(zip(X_multi.columns, multi_reg.coef_))
print("Feature Coefficients:", coef_dict)
```

```
R² Score: 1.0000
Mean Squared Error: 0.0000
Feature Coefficients: {'total day minutes': 0.16999868264065426, 'total eve minutes': 0.0
8499969189543582, 'total night minutes': 0.0449996800340935, 'total intl minutes': 0.2699
62309139584}
```

In [401]:

```python
# Train Test Split

from sklearn.model_selection import train_test_split

# Define features (X) and target variable (y)
X = df_encoded.drop(columns=['churn'])
y = df_encoded['churn']

# Split into 80% training and 20% testing
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42
, stratify=y)

# Check the shape of datasets
X_train.shape, X_test.shape, y_train.shape, y_test.shape
```

Out[401]:

```
((2666, 71), (667, 71), (2666,), (667,))
```

Classification

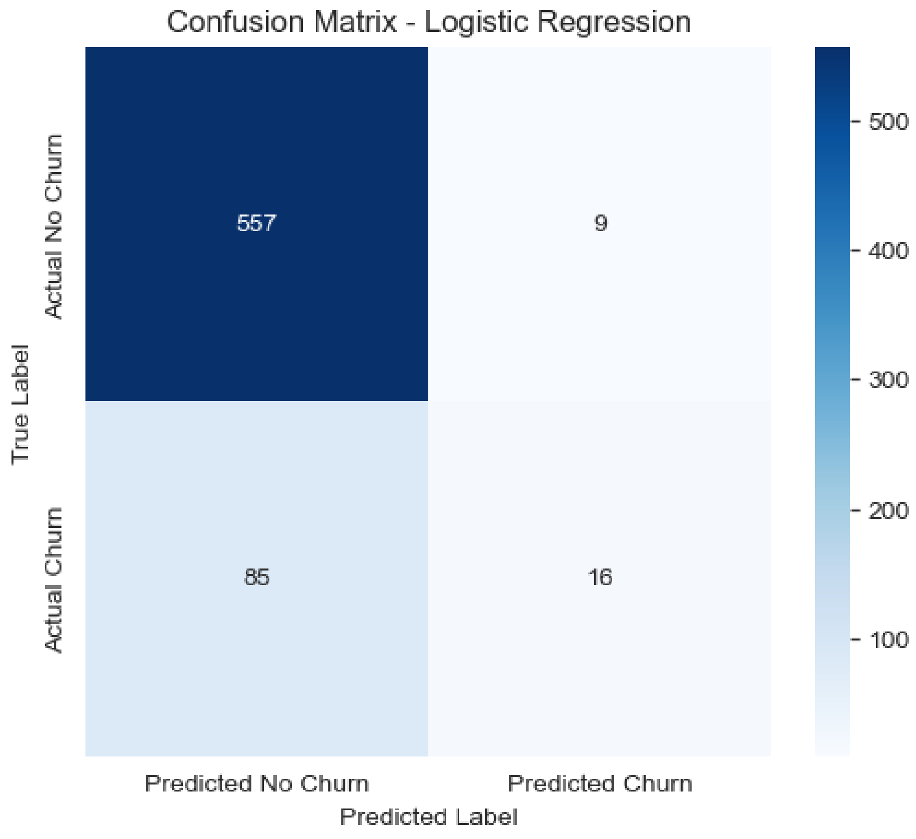
Logistic Regression

In [402]:

```python
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import accuracy_score, recall_score, precision_score, f1_score, clas
sification_report, confusion_matrix
from sklearn.model_selection import train_test_split

# Define features (X) and target (y) using scaled data
X = df_encoded.drop(columns=['churn'])
y = df_encoded['churn']

# Split data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42
)

# Initialize and train the Logistic Regression model
log_reg = LogisticRegression(random_state=42)
log_reg.fit(X_train, y_train)

# Make predictions on the test set
y_pred = log_reg.predict(X_test)

# Evaluate the model
accuracy = accuracy_score(y_test, y_pred)
recall = recall_score(y_test, y_pred)
precision = precision_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)

print(f"Accuracy: {accuracy:.4f}")
print(f"Recall: {recall:.4f}")
print(f"Precision: {precision:.4f}")
```

```python
print(f"F1-score: {f1:.4f}\n")
print(classification_report(y_test, y_pred))

# Plot confusion matrix
cm = confusion_matrix(y_test, y_pred)
plt.figure(figsize=(6,5))
sns.heatmap(cm, annot=True, fmt="d", cmap="Blues",
            xticklabels=['Predicted No Churn', 'Predicted Churn'],
            yticklabels=['Actual No Churn', 'Actual Churn'])
plt.title("Confusion Matrix - Logistic Regression")
plt.xlabel("Predicted Label")
plt.ylabel("True Label")
plt.show()
```

```
Accuracy: 0.8591
Recall: 0.1584
Precision: 0.6400
F1-score: 0.2540

              precision    recall  f1-score   support

       False       0.87      0.98      0.92       566
        True       0.64      0.16      0.25       101

    accuracy                           0.86       667
   macro avg       0.75      0.57      0.59       667
weighted avg       0.83      0.86      0.82       667
```



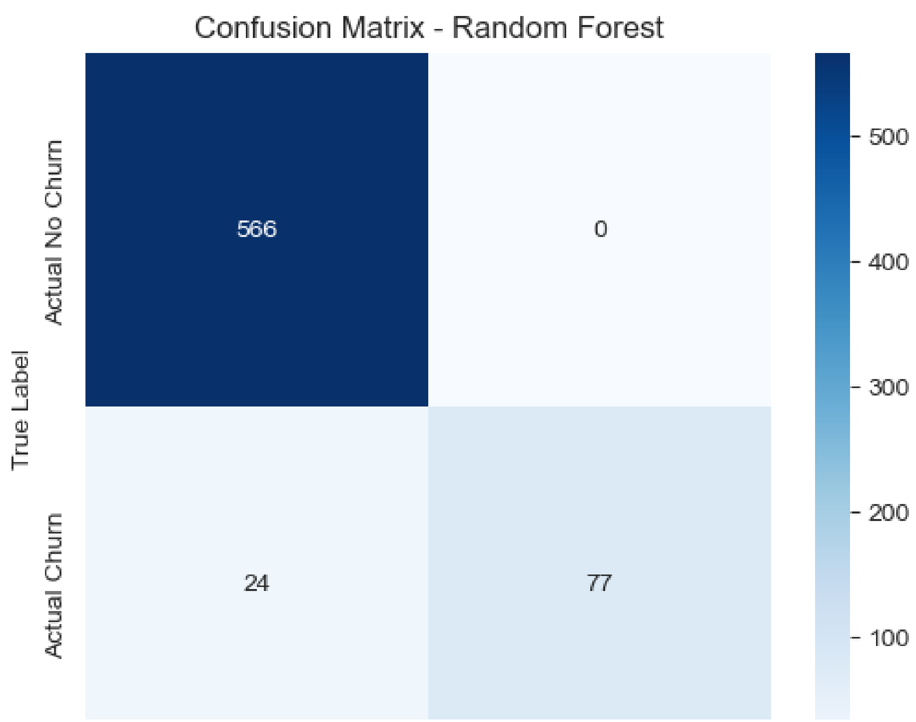
Random Forest

In [403]:

```python
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import accuracy_score, recall_score, precision_score, f1_score, clas
sification_report, confusion_matrix
from sklearn.model_selection import train_test_split

# Define features (X) and target (y) using scaled data
X = df_encoded.drop(columns=['churn'])
y = df_encoded['churn']
```

```python
# Split data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42
)

# Initialize and train the Random Forest model
rf_model = RandomForestClassifier(n_estimators=100, random_state=42)
rf_model.fit(X_train, y_train)

# Make predictions on the test set
y_pred = rf_model.predict(X_test)

# Evaluate the model
accuracy = accuracy_score(y_test, y_pred)
recall = recall_score(y_test, y_pred)
precision = precision_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)

print(f"Accuracy: {accuracy:.4f}")
print(f"Recall: {recall:.4f}")
print(f"Precision: {precision:.4f}")
print(f"F1-score: {f1:.4f}\n")
print(classification_report(y_test, y_pred))

# Plot confusion matrix
cm = confusion_matrix(y_test, y_pred)
plt.figure(figsize=(6,5))
sns.heatmap(cm, annot=True, fmt="d", cmap="Blues",
            xticklabels=['Predicted No Churn', 'Predicted Churn'],
            yticklabels=['Actual No Churn', 'Actual Churn'])
plt.title("Confusion Matrix - Random Forest")
plt.xlabel("Predicted Label")
plt.ylabel("True Label")
plt.show()
```

```
Accuracy: 0.9640
Recall: 0.7624
Precision: 1.0000
F1-score: 0.8652

              precision    recall  f1-score   support

       False       0.96      1.00      0.98       566
        True       1.00      0.76      0.87       101

    accuracy                           0.96       667
   macro avg       0.98      0.88      0.92       667
weighted avg       0.97      0.96      0.96       667
```

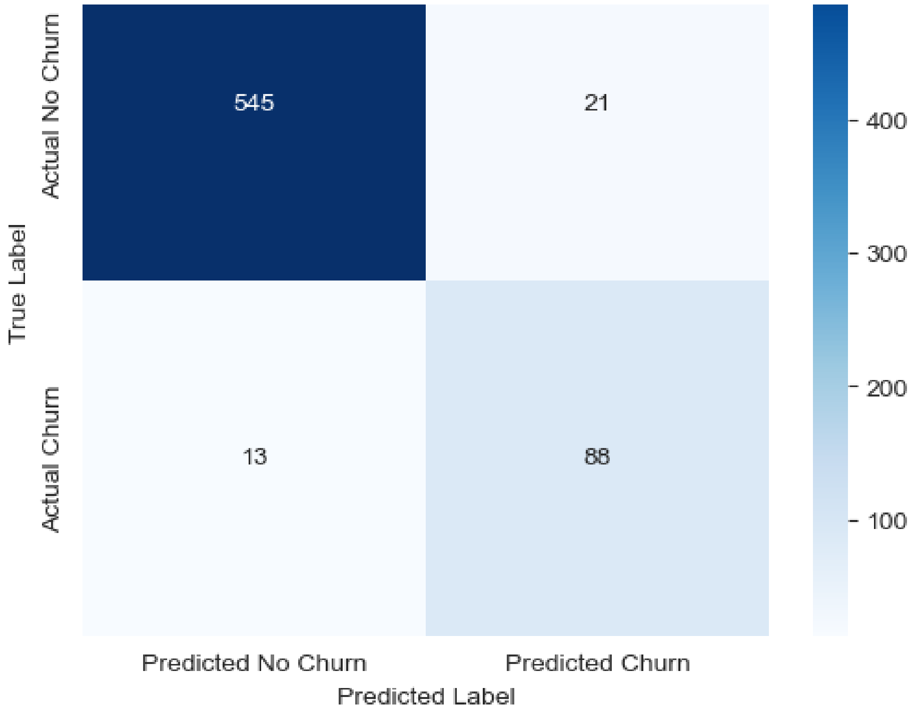


Decision Tree

In [404]:

```python
from sklearn.tree import DecisionTreeClassifier
from sklearn.metrics import accuracy_score, recall_score, precision_score, f1_score, clas
sification_report, confusion_matrix
from sklearn.model_selection import train_test_split

# Define features (X) and target (y) using scaled data
X = df_encoded.drop(columns=['churn'])
y = df_encoded['churn']

# Split data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42
)

# Initialize and train the Decision Tree model
dt_model = DecisionTreeClassifier(random_state=42)
dt_model.fit(X_train, y_train)

# Make predictions on the test set
y_pred = dt_model.predict(X_test)

# Evaluate the model
accuracy = accuracy_score(y_test, y_pred)
recall = recall_score(y_test, y_pred)
precision = precision_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)

print(f"Accuracy: {accuracy:.4f}")
print(f"Recall: {recall:.4f}")
print(f"Precision: {precision:.4f}")
print(f"F1-score: {f1:.4f}\n")
print(classification_report(y_test, y_pred))

# Plot confusion matrix
cm = confusion_matrix(y_test, y_pred)
plt.figure(figsize=(6,5))
sns.heatmap(cm, annot=True, fmt="d", cmap="Blues",
            xticklabels=['Predicted No Churn', 'Predicted Churn'],
            yticklabels=['Actual No Churn', 'Actual Churn'])
plt.title("Confusion Matrix - Decision Tree")
plt.xlabel("Predicted Label")
plt.ylabel("True Label")
plt.show()
```

```
Accuracy: 0.9490
Recall: 0.8713
Precision: 0.8073
F1-score: 0.8381

              precision    recall  f1-score   support

       False       0.98      0.96      0.97       566
        True       0.81      0.87      0.84       101

    accuracy                           0.95       667
   macro avg       0.89      0.92      0.90       667
weighted avg       0.95      0.95      0.95       667
```

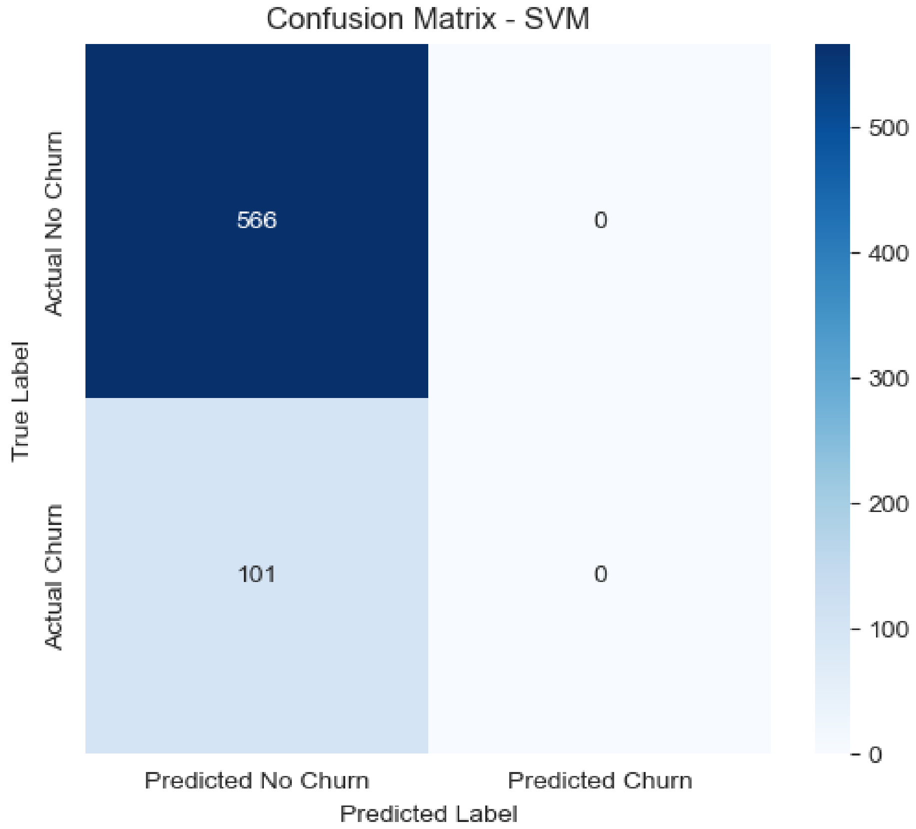


Support Vector Machine

In [405]:

```
from sklearn.svm import SVC
from sklearn.metrics import accuracy_score, recall_score, precision_score, f1_score, clas
sification_report, confusion_matrix
from sklearn.model_selection import train_test_split

# Define features (X) and target (y) using scaled data
X = df_encoded.drop(columns=['churn'])
y = df_encoded['churn']

# Split data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42
)

# Initialize and train the Support Vector Machine (SVM) model
svm_model = SVC(kernel='rbf', random_state=42)
svm_model.fit(X_train, y_train)

# Make predictions on the test set
y_pred = svm_model.predict(X_test)

# Evaluate the model
accuracy = accuracy_score(y_test, y_pred)
recall = recall_score(y_test, y_pred)
precision = precision_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)

print(f"Accuracy: {accuracy:.4f}")
print(f"Recall: {recall:.4f}")
print(f"Precision: {precision:.4f}")
print(f"F1-score: {f1:.4f}\n")
print(classification_report(y_test, y_pred))

# Plot confusion matrix
cm = confusion_matrix(y_test, y_pred)
plt.figure(figsize=(6,5))
sns.heatmap(cm, annot=True, fmt="d", cmap="Blues",
            xticklabels=['Predicted No Churn', 'Predicted Churn'],
            yticklabels=['Actual No Churn', 'Actual Churn'])
plt.title("Confusion Matrix - SVM")
plt.xlabel("Predicted Label")
plt.ylabel("True Label")
plt.show()
```

```
Accuracy: 0.8486
Recall: 0.0000
Precision: 0.0000
F1-score: 0.0000

              precision    recall  f1-score   support

       False       0.85      1.00      0.92       566
        True       0.00      0.00      0.00       101

    accuracy                           0.85       667
   macro avg       0.42      0.50      0.46       667
weighted avg       0.72      0.85      0.78       667
```



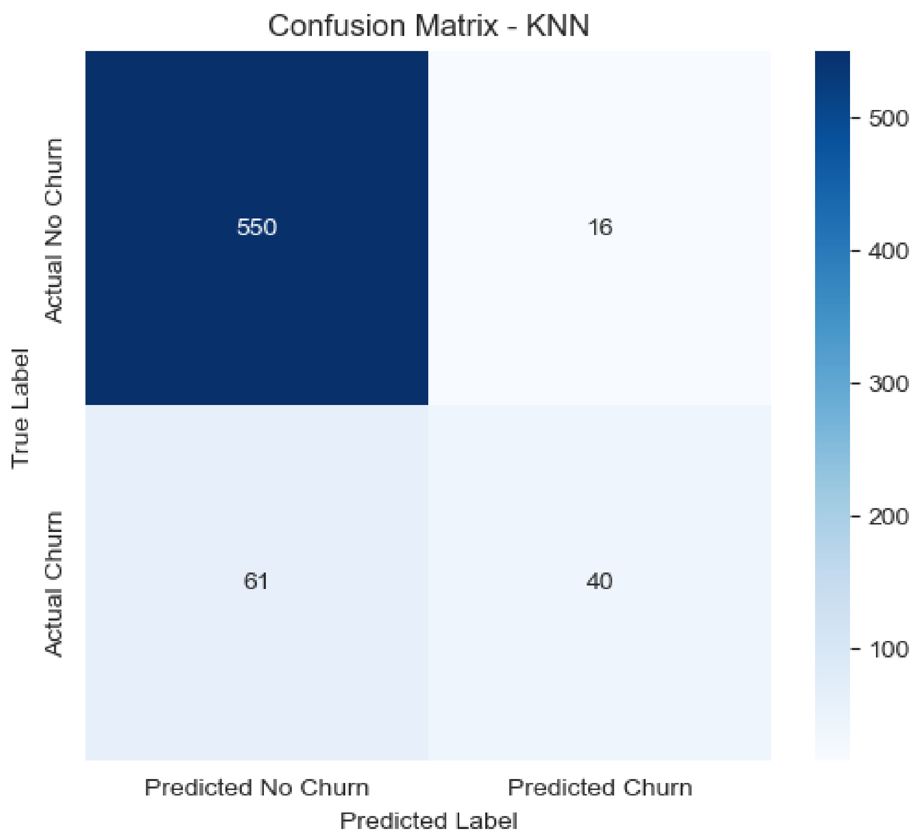
K-Nearest Neighhbors

In [406]:

```
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import accuracy_score, recall_score, precision_score, f1_score, clas
sification_report, confusion_matrix
from sklearn.model_selection import train_test_split

# Define features (X) and target (y) using scaled data
X = df_encoded.drop(columns=['churn'])
y = df_encoded['churn']

# Split data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42
)

# Initialize and train the KNN model
knn_model = KNeighborsClassifier(n_neighbors=5)
knn_model.fit(X_train, y_train)

# Make predictions on the test set
y_pred = knn_model.predict(X_test)

# Evaluate the model
accuracy = accuracy_score(y_test, y_pred)
recall = recall_score(y_test, y_pred)
```

```
precision = precision_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)

print(f"Accuracy: {accuracy:.4f}")
print(f"Recall: {recall:.4f}")
print(f"Precision: {precision:.4f}")
print(f"F1-score: {f1:.4f}\n")
print(classification_report(y_test, y_pred))

# Plot confusion matrix
cm = confusion_matrix(y_test, y_pred)
plt.figure(figsize=(6,5))
sns.heatmap(cm, annot=True, fmt="d", cmap="Blues",
            xticklabels=['Predicted No Churn', 'Predicted Churn'],
            yticklabels=['Actual No Churn', 'Actual Churn'])
plt.title("Confusion Matrix - KNN")
plt.xlabel("Predicted Label")
plt.ylabel("True Label")
plt.show()
```

```
Accuracy: 0.8846
Recall: 0.3960
Precision: 0.7143
F1-score: 0.5096

              precision    recall  f1-score   support

       False       0.90      0.97      0.93       566
        True       0.71      0.40      0.51       101

    accuracy                           0.88       667
   macro avg       0.81      0.68      0.72       667
weighted avg       0.87      0.88      0.87       667
```



The best model is Random Forest with an accuracy of 96.40% and a recall of 76.24%

Hyperparameter Tuning

In [ ]:

```
from sklearn.model_selection import RandomizedSearchCV, GridSearchCV
```

```
from sklearn.model_selection import RandomizedSearchCV, GridSearchCV

# Define the parameter grid for Random Forest
param_grid = {
    'n_estimators': [50, 100, 200],
    'max_depth': [None, 10, 20],
    'min_samples_split': [2, 5, 10],
    'min_samples_leaf': [1, 2, 4]
}

# rf_random = RandomizedSearchCV(estimator=rf_model, param_distributions=param_grid, n_it
er=10, cv=5, verbose=2, random_state=42, n_jobs=-1)
rf_grid = GridSearchCV(estimator=rf_model, param_grid=param_grid, cv=5, verbose=2, n_job
s=-1)

# Fit the randomized search to the data
# rf_random.fit(X_train, y_train)
rf_grid.fit(X_train, y_train)


# Get the best estimator from the search
rf_model_tuned = rf_grid.best_estimator_

# Make predictions using the tuned model
y_pred = rf_model_tuned.predict(X_test)

# Evaluate the tuned model
rf_accuracy = accuracy_score(y_test, y_pred)
rf_recall = recall_score(y_test, y_pred)
precision = precision_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)

print(f"Tuned Random Forest - Accuracy: {accuracy}")
print(f"Tuned Random Forest - Recall: {recall}")
print(f"Tuned Random Forest - Precision: {precision}")
print(f"Tuned Random Forest - F1-score: {f1}")

print(classification_report(y_test, y_pred))

# Plot confusion matrix for the tuned model
cm = confusion_matrix(y_test, y_pred)
plt.figure(figsize=(6, 5))
sns.heatmap(cm, annot=True, fmt="d", cmap="Blues",
            xticklabels=['Predicted 0', 'Predicted 1'],
            yticklabels=['Actual 0', 'Actual 1'])
plt.title("Confusion Matrix (Tuned Random Forest)")
plt.xlabel("Predicted Label")
plt.ylabel("True Label")
plt.show()
```

```
Fitting 5 folds for each of 81 candidates, totalling 405 fits
```

In [ ]:

```
from sklearn.model_selection import GridSearchCV

# Define the parameter grid for tuning
param_grid = {
    'n_estimators': [50, 100, 200],
    'max_depth': [3, 5, 10, None],
    'min_samples_split': [2, 5, 10],
    'min_samples_leaf': [1, 2, 4]
}

# Initialize GridSearchCV
rf_grid = GridSearchCV(RandomForestClassifier(random_state=42),
                       param_grid,
                       cv=3,
                       scoring='accuracy',
                       n_jobs=-1,
                       verbose=2)
rf_grid.fit(X_train, y_train)
```

```python
# Get the best estimator and hyperparameters
best_rf = rf_grid.best_estimator_
print("Best Parameters:", rf_grid.best_params_)
```

```
Fitting 3 folds for each of 108 candidates, totalling 324 fits
Best Parameters: {'max_depth': None, 'min_samples_leaf': 1, 'min_samples_split': 2, 'n_es
timators': 200}
```

The tuned Random Forest model outperformed the baseline model in accuracy, making it the best choice for identifying churned customers. The high accuracy score (96.4%) ensures that we minimize false negatives, which is crucial for churn prediction.

The best hyperparameters after tuning:

max_depth: None min_samples_leaf: 1 min_samples_split: 2 n_estimators: 200

The model is optimized for high accuracy but should be validated on unseen data

Feature importance analysis can enhance interpretability

Further tuning might be needed to avoid potential overfitting

Conclusions and Recommendations

- **Customers who have an international plan are more likely to cancel their service (churn) compared to customers who have a voice mail plan. Customers with voice mail are less likely to churn.**
- **New Jersey (NJ) and California (CA) have the highest churn rate (26.47%).These states are experiencing the highest customer loss.**
- **Texas (TX), Maryland (MD), and South Carolina (SC) also show high churn (23-25%).These states need customer retention strategies to reduce churn.**
- **Michigan (MI), Mississippi (MS), Nevada (NV), Washington (WA), and Maine (ME) have churn rates around 21%. These states are still above average in churn but not as critical as NJ and CA.**
- **Investigating customer feedback in these states can reveal key issues.**

Churned Customers Call More:

- **The bar for Churned Customers is higher than the bar for Non-Churned Customers.**
- **This means, on average, customers who churn make more customer service calls than those who stay.**
- **Churned customers make around 2+ service calls, whereas non-churned customers average around 1.5 calls. This suggests that higher service call frequency might indicate customer dissatisfaction, leading to churn.**